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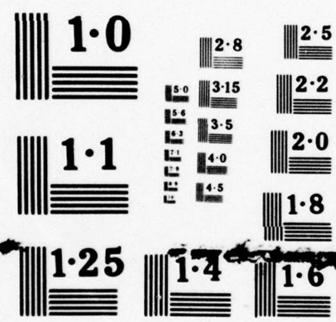

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COMMUNICATION SYSTEM PERFORMANCE MODEL FOR VHF AND HIGHER FREQUENCIES

DEPARTMENT OF COMMERCE · UNITED STATES OF AMERICA

OT

U.S. DEPARTMENT OF COMMERCE Office of Telecommunications

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OT REPORT 77-128

COMMUNICATION SYSTEM PERFORMANCE MODEL FOR VHF AND HIGHER FREQUENCIES

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OFFICE OF TELECOMMUNICATIONS
John M. Richardson, Director

October 1977

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OFFICE OF TELECOMMUNICATIONS
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PREFACE

The model development work reported herein was accomplished with funds provided by the U. S. Army Communications Command, Communications Electronics Engineering Installation Agency, under Project Order Number CC-016-76. However, this report addresses only a portion of the work funded under that project order number.

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COMMUNICATION SYSTEM PERFORMANCE MODEL FOR VHF AND HIGHER FREQUENCIES

R.D. Jennings and S.J. Paulson*

Communication system designers and engineers often must decide whether to use design-aid models not well suited to the problem at hand or to perform many tedious and laborious hand calculations which, coupled with certain "rules of thumb," provide an estimate of system performance. The model documented in this report provides relief from such problems. For communication systems which operate at VHF and higher frequencies, the character of the terrain between the transmitting and receiving antennas, as well as the heights of the antennas above immediate terrain, will affect significantly the attenuation of the radio signals. The model reported herein considers these terrain influences, along with other commonly considered influences, by automatically accessing digitized topographic data files to develop the path data needed to compute the basic transmission loss. Computation of the basic transmission loss is accomplished using the Longley-Rice formulation for point-to-point paths. The statistical character of the basic transmission loss results from long-term fading (time availability), path to path differences (location variability), and prediction confidence considered in the model. The type of model output data is selected by the user. Options range from simple path terrain information to basic transmission losses to utilizations of the basic transmission loss in computing power density or received signal level. There is, in addition, an output option which portrays predicted communication reliability as the probability that received signal level will exceed a specified threshold for specified conditions of time availability and location variability. All output options will provide data in either tabular or plotted form. Plotted output data are contoured over a geographical area not to exceed two degrees latitude by two degrees longitude.

Key Words: Basic transmission loss; communication; communication reliability; communication system performance; computer model; received signal level; path profile; power density; propagation; propagation loss.

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1. INTRODUCTION

The U.S. Army Communication Command (USACC), with general, world-wide responsibilities for Army communications, includes the U.S. Army Communications Electronics Engineering Installation Agency (CEEIA). The CEEIA has the technical responsibilities for designing and installing the Army's strategic and tactical communications, so that required system performance criteria are satisfied. Sophisticated techniques are available to aid in the design of fixed-point-to-fixed-point communication links. Such aids usually use a propagation loss model generally referred to as a "point-to-point" loss model. Aids also are available for predicting the performance of land mobile and broadcast types of radio communications. By contrast, these aids usually employ a propagation loss model called an "area prediction" loss model. The area prediction models use <u>average</u> values to describe the propagation path rather than specific values as is done in a point-to-point loss model. Other frequently used design aids involve tedious and laborious hand calculations and/or employing "rules of thumb" to estimate the performance of a communication system.

Application of the more specific techniques of a point-to-point propagation loss model to a large number of paths in order to predict the performance of mobile and/or broadcast types of radio systems is, in essence, the approach of the automated model documented by this report. The situation can be described as fixed-point-to-mobile-point communications. The application of a point-to-point loss model to such situations involves the definition of a large array of points within a defined geographical area. Each point linked with the fixed-point location is treated as a point-to-point path for purposes of estimating the propagation loss between those points. The CEEIA has identified a need for this type of communication system design aid to provide evaluation of communication system performance in such terms as received signal level or communication reliability (defined in Appendix F). This capability is defined and discussed in this report.

The next section of the report presents a discussion of typical application for the model, section 3 is a general description of the model, section 4 lists a summary of important model features and output data options, and section 5 discusses recommendations for improvement of the model. The detailed User's Guide for the model is Appendix A, and Appendix B is the

Software Technical Description. Technical details of the point-to-point propagation loss model; the path profile and path parameter calculation routines; power density, received signal level, and communication reliability calculations; and other aspects of the model are discussed in the remaining appendices.

2. TYPICAL APPLICATION

In a more specific context than the preceding introduction has revealed, the Communication System Performance Model (CSPM) has been developed to provide Army communication system designers and engineers an ability to predict the expected performance of the line-of-sight (LOS) and tropospheric scatter communication systems to be installed in support of the Tri-Service Tactical (TRITAC) communication system and various other local Ft. Huachuca communication systems. These specific applications have not dictated any model limitations, however.

Suppose, for example, that the communication performance of mobile and semi-mobile units linked with a well-sited, fixed installation is to be evaluated. An engineer performing this evaluation will know the transmitter output power and the antenna heights above ground and gains for the fixed installation and the mobile and semi-mobile units. Furthermore, he will have determined that satisfactory system performance will be realized when the received signal level (that is, the signal level delivered by the receiving antenna to the input port of the receiver) is greater than some threshold value for the received signal level.

Since the problem involves mobile and semi-mobile systems, the evaluation must consider communication between any point within some geographical area and the fixed-installation location. The estimates of propagation losses, then, could be calculated using average values to describe certain essential terrain characteristics required by the propagation loss model.

However, suppose the engineer decides that he needs better-defined estimates than can be calculated using average characteristics. He decides that estimates of propagation loss calculated by using a point-to-point propagation loss model will be satisfactory, since the model for such estimates uses specific characteristics rather than average characteristics for each propagation path. With sufficient numbers of such calculations for specific

point-to-point propagation paths throughout the geographical area, the communication system performance from any point in the area linked with the fixed point is approximated very well. The CSPM provides this type of information.

First, however, one must realize that propagation loss is a variable phenomenon, even for a defined, specific path, due to meteorological variations. Furthermore, there will be additional variation from path to path, due in part to the fact that different paths can be described with the same model input path descriptor values. Finally, there is uncertainty associated with the prediction because finite sampling has supported the development of the prediction model, and influences which do exist are not modeled explicitly.

The CSPM, then, provides statistical estimates of basic transmission loss for a large number of propagation paths throughout a geographical area. The basic transmission loss estimates are used to calculate statistical estimates of power density and received signal level. Also, the statistical nature of basic transmission loss is utilized to provide an output describing communication reliability throughout the geographical area for specified time and location variabilities. An incidental dividend of the model is the option for output data which describe the terrain profile of a propagation path.

In order to use the CSPM to evaluate the problem outlined earlier, the engineer must define the statistical levels at which the satisfactory performance criterion must be met. Suppose, then, that received signal level (as a function of specified time availability, q_T, and location variability, q_L) greater than the threshold received signal level will provide satisfactory service. The communication reliability calculation capability of the CSPM can be used to provide output data which show the probability--communication reliability--with which these conditions can be expected throughout the geographical area. In addition, other values for time availability and location variability can be used to explore the impact of tradeoffs that may be necessary to consider such as reducing the value for location variability while maintaining the value for time availability. The statistical concepts of time availability and location variability are discussed in Appendix C.

These model outputs for a hypothetical problem are shown in Figures 2-1 and 2-2. This type of data is typical for the model being used in its "most powerful" form, so to speak. Several "reduced-power" applications also are available.

For example, the same problem may be considered without knowing, or at least without defining, a threshold for received signal level. That is, no criterion for system performance evaluation is known or defined. Now, the model could be asked to calculate and plot up to ten equal-value contours of received signal level throughout the geographical area of interest. These plots would be provided for specified values for the variabilities--time availability, location variability, and prediction confidence. Such an output is illustrated by Figure 2-3.

A further reduction in defining the input data for the model can be accommodated by asking the model to provide equal-value contours of power density. These data may be obtained without knowing (or specifying) the receiving antenna gain. Or perhaps in the early stages of defining a problem, neither the transmitting nor the receiving antenna gain is known. Then the model user may be interested in contours of basic transmission loss. For such data, the transmitter output power also would not need to be known or specified.

If contours of power density or basic transmission loss were produced for the same problem used to generate the received signal level contours shown in Figure 2-3, the contours would have very similar shapes. This would occur because the calculated values for received signal level, power density, and basic transmission loss at each point have constant differences. Power density is different from received signal level by a constant value which accounts for the receiving antenna gain, appropriate aperture-to-medium coupling loss adjustments, and the free-space propagation loss. Basic transmission loss is different from received signal level by a constant value equaling the sum of the transmitter output power, the transmitting and receiving antenna gains, and the appropriate aperture-to-medium coupling loss adjustments. The concepts of communication reliability, received signal level, power density, and basic transmission loss are discussed in Appendix F.

Any of these types of output data may be requested by a user if he specifies only the transmitter coordinates (and receiver coordinates, if

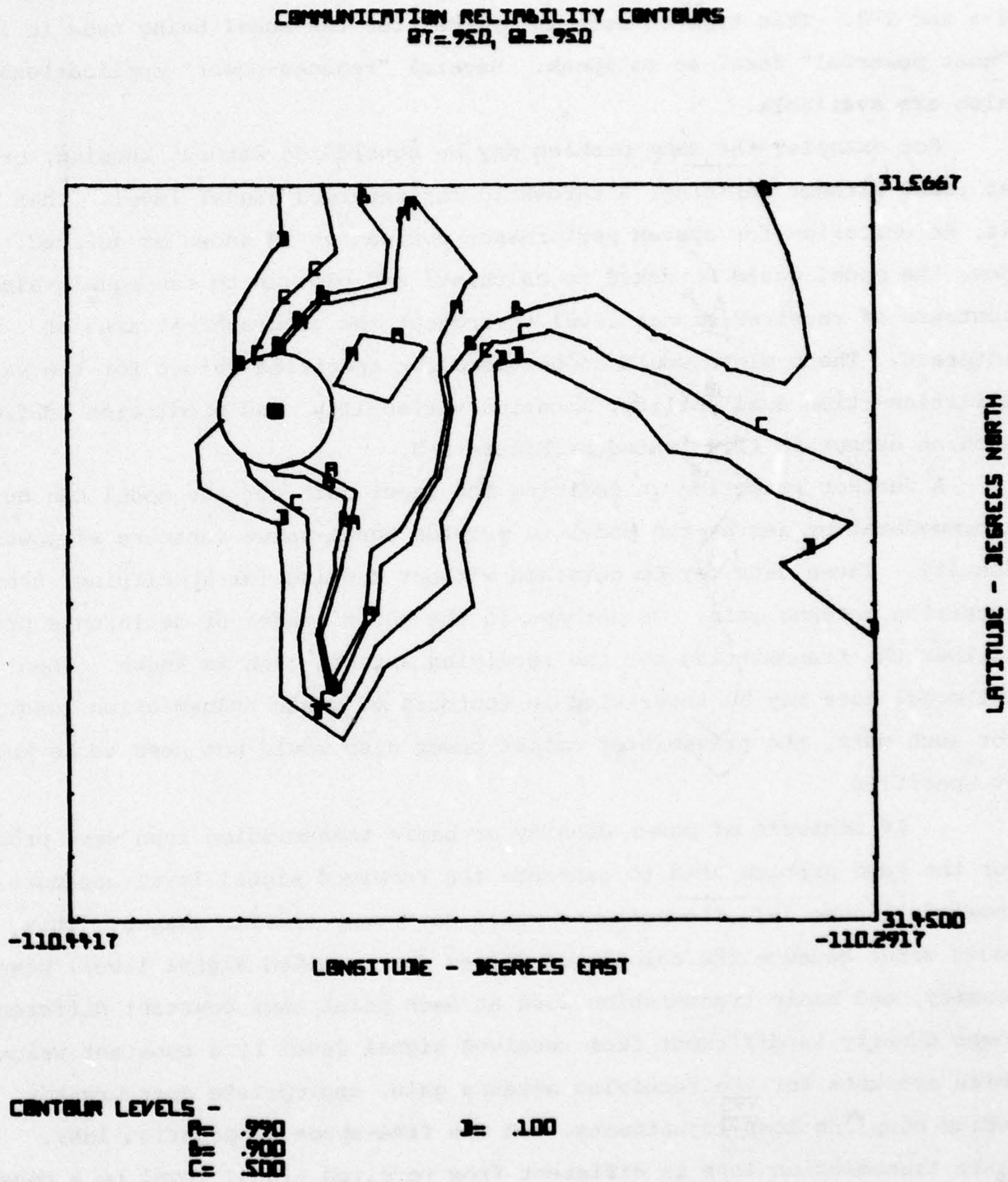

Figure 2-1. Communication reliability throughout a geographical area for conditions of time availability = 0.95 and location variability = 0.95.

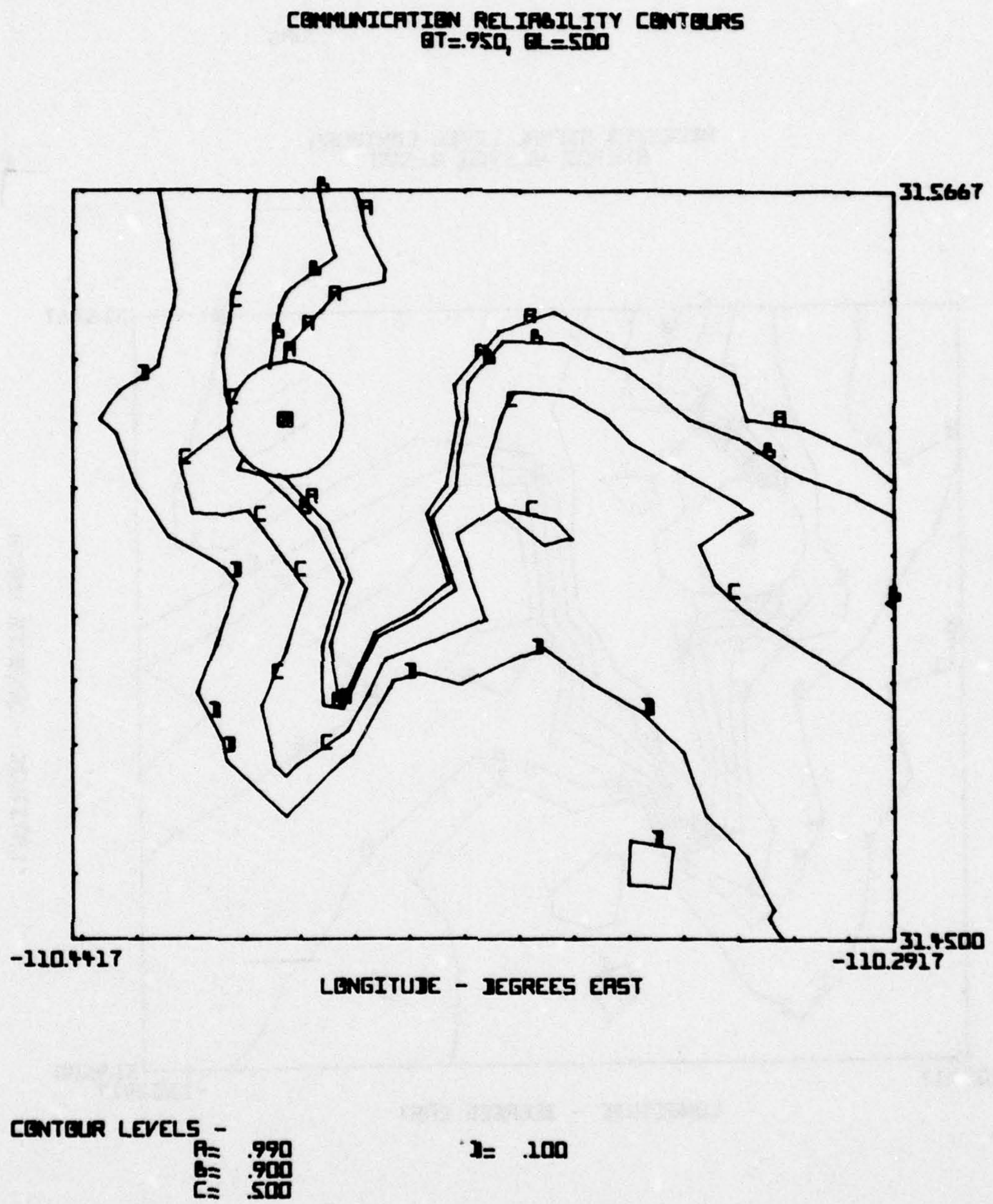

Figure 2-2. Communication reliability throughout a geographical area for conditions of time availability = 0.95 and location variability = 0.50.

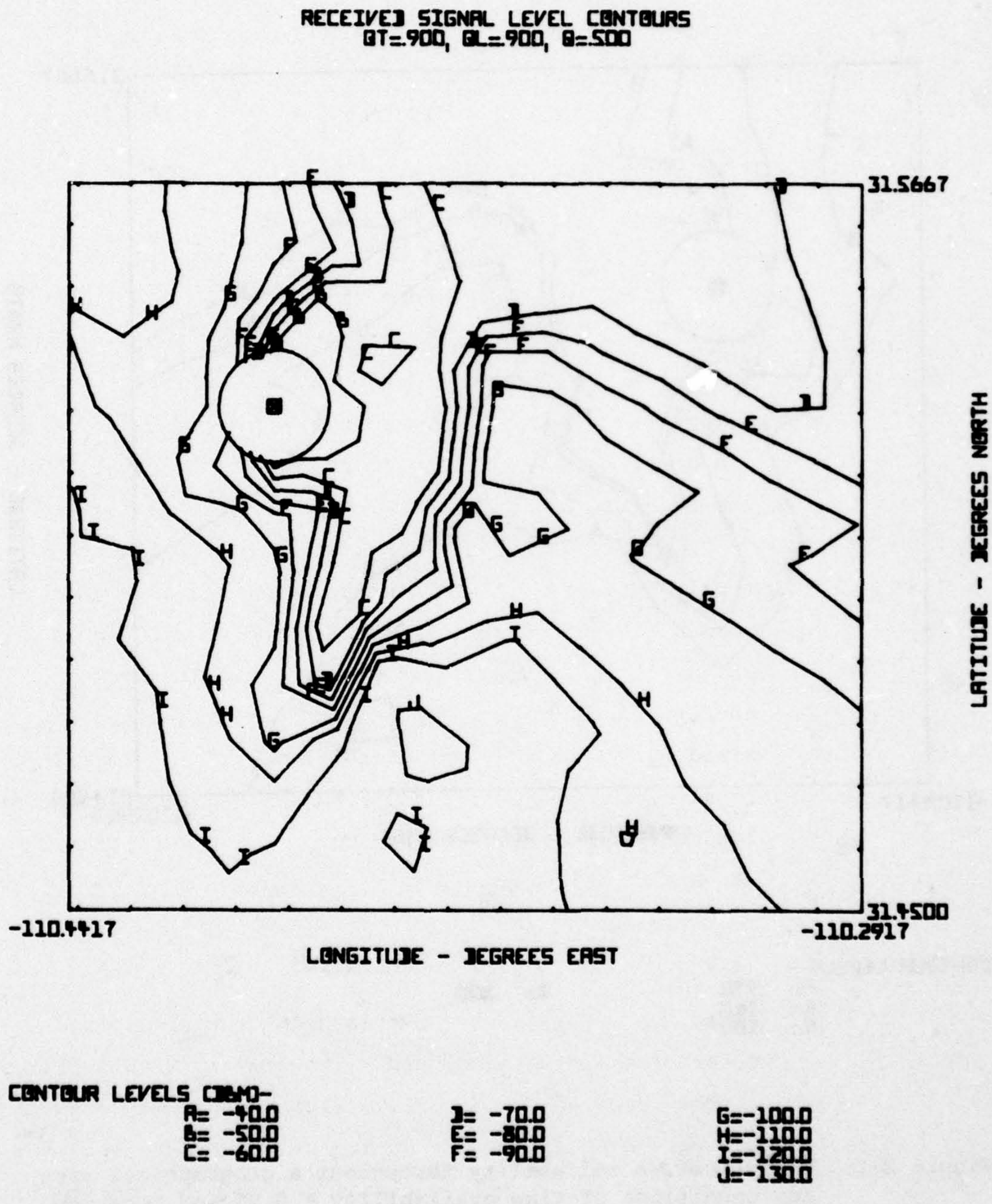

Figure 2-3. Received signal level throughout a geographical area for conditions of time availability = 0.90 and location variability = 0.90, and confidence = 0.50.

a path profile is requested), since the model has built-in default values for all other input data. Of course, the use of the model must evaluate the output data, making some subjective judgment about how well the default conditions represent his problem. In addition to the plotted data, each type of output data may be requested in a tabulated form as well.

3. MODEL DESCRIPTION

Though designed for machine independence, a CDC-6500 system will be employed by the Army for applying the model to communication system performance evaluations. The model has been designed to provide flexibility for the user in his study of existing or proposed communication systems. The model user may define a single communication path or a geographical area throughout which communication is desired. The model will extract terrain data from a digitized topographic data file, use the extracted data to construct path profiles, and calculate appropriate path parameter data. The path parameter data are required by the point-to-point propagation loss model which calculates estimates of basic transmission loss (L_b) which may be used in subsequent calculations of power density (P_d), received signal level (RSL), and/or communication reliability (REL). The user selected outputs of L_b, P_d, RSL, and/or REL, as well as path profile data, are provided in tabular and/or plotted form. When communication reliability is specified as a desired output, a received signal level threshold (RSL_{TH}) for system performance also must be specified. Detailed technical description of the model is provided in Appendix B, Software Technical Description, and Appendices C, D, E, and F.

3.1 Model (Program) Organization

The model is divided into four program overlays, so that reasonable requirements for computer core are not exceeded. The organization is illustrated in Figure 3-1. The primary (0,0) overlay, with program CSPM as the overlay controller, provides overall program control. The source code for program CSPM contains a commentary on the model and the common block variable definitions for /OPTIONS/ and /LOSSMOD/. Program CSPM calls the appropriate secondary overlays to accomplish program execution.

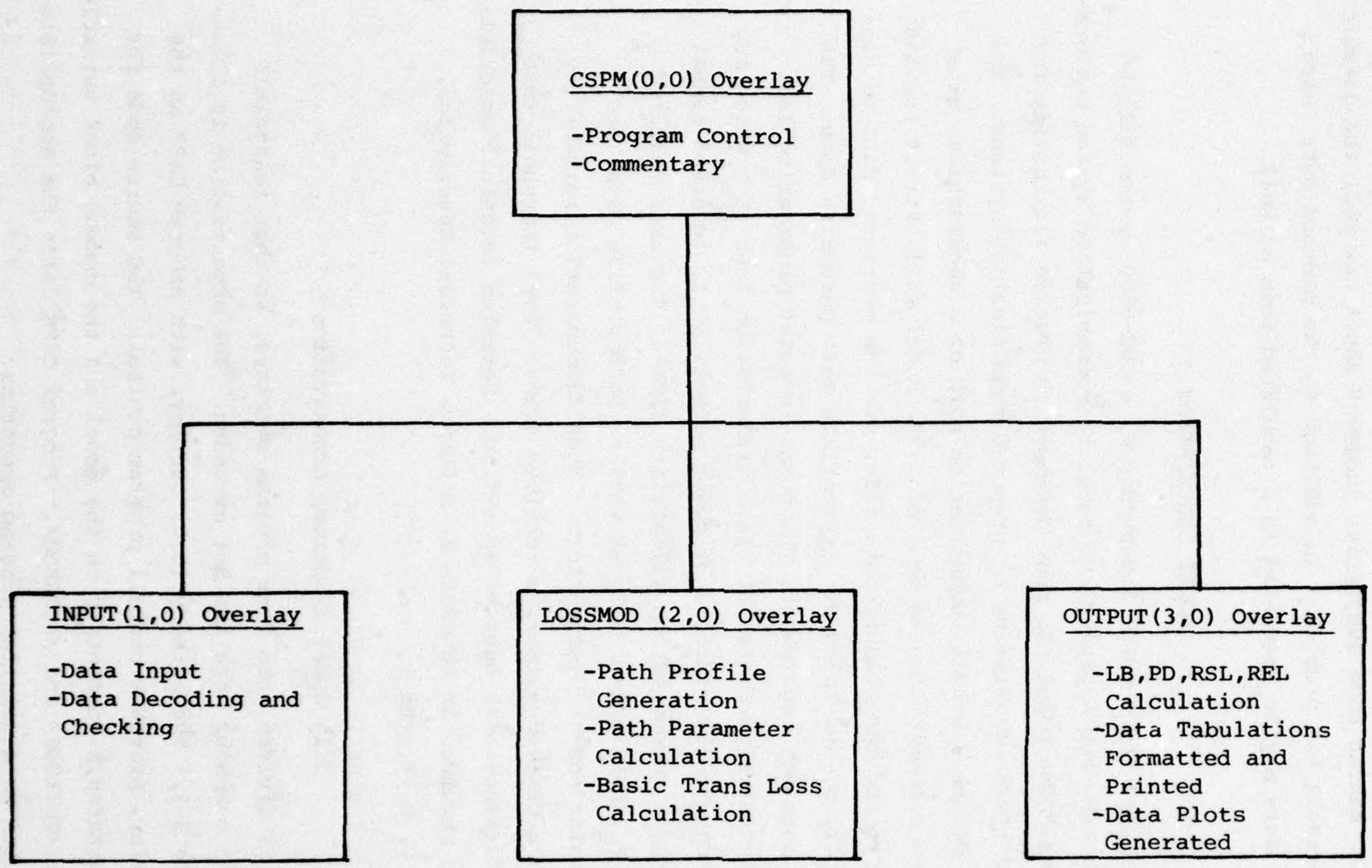

Figure 3-1. CSPM overlay structure.

The (1,0) secondary overlay, with program INPUT as the overlay controller, reads the input in free format, then lists, decodes, verifies, and limit checks the input data. An input data summary, preceded by error messages as appropriate, also is printed.

Path profile generation and path parameter calculation routines, along with the basic transmission loss model, are contained in the (2,0) overlay with program LOSSMOD as the overlay controller. A topographic data file, containing terrain elevation at 30" intervals in latitude and longitude for the continental United States (CONUS), is accessed to obtain data to generate the path profile. The path profiles provide the necessary information for calculating the path parameter data (elevation of and distance to the radio horizon for each antenna and the average elevation of the terrain foreground for each antenna) required as input to the point-to-point propagation loss model. The loss model is the Longley-Rice model used in the point-to-point mode. The loss model computes statistical estimates of basic transmission loss as a function of distance. The final computation providing the basic transmission loss is done in the (3,0) secondary overlay, where all output calculations are performed. But all parameters required for that calculation are computed in the (2,0) overlay and written to a file for use in the calculations of not only basic transmission loss but also power density, received signal level, and communication reliability in the (3,0) overlay. Single path or geographical area data are plotted and/or tabulated in the (3,0) overlay, according to specifications by the user.

3.2 Description of Input Data

The input data serve to define the type of output desired by the model user as well as the conditions to be applied in the calculations of basic transmission loss, power density, received signal level, and communication reliability. No attempt is made in this section to discuss the physical basis or rationale of the propagation loss model. Rather, some familiarity with the model is assumed. If that familiarity is lacking, the reader is referred to Appendix C and the references by Longley and Rice (1968), Rice et al. (1967), Longley (1976), private communications with Longley et al. (1971), and Hufford (1972) (available from the authors) which discuss the model in considerable detail.

The first input data card must be a title for the run. Following the title and starting with the next card of the input data deck, the input data may be specified in any order with multiple items of data on each card. However, an item of data may not begin on one card and end on another card. The data are specified by using keywords (shown in capital letters in this discussion) for each item of data. Default values for most of the data items are built into the model.

Title. The title, provided by the first input data card, will be printed on the output data tabulations and plots. Up to 60 characters, including blanks, may be used.

Type of output data. Various selections for the output data are available. The following list indicates most of the possible selections.

- Tabulated path profile data.
- Plotted path profile data.
- Tabulated values of LB, PD, RSL, and/or REL for a geographical area, with or without path profile data for selected radials.
- Plotted values of LB, PD, RSL, and/or REL for a geographical area, with or without path profile data for selected radials.

A specification of PATH will provide path profile data for a single propagation path. Basic transmission loss also may be obtained for the path by specifying LB. Specifying MAP will result in the production of LB, data for a geographical area 1^{o} in latitude by 1^{o} in longitude with the transmitter located in the center of the area. Power density, received signal level, or communication reliability also may be obtained for the geographical area by appropriately specifying PD, RSL, or REL. Specifying MAP = (1st latitude/2nd latitude/1st longitude/2nd longitude) will produce LB, PD, RSL, and/or REL data for the geographical area thus defined. The maximum allowed area size is 2^{o} latitude by 2^{o} longitude. The transmitter may be specified at any location within the area.

Two additional keywords which pertain to the output of path profile data are PRO, denoting plotted profile data, and PTAB, denoting tabular profile data. When the input data contain PATH, PRO, only plotted profile data are provided. Specifying PATH means that PTAB will result in only tabulated profile data. However, specifying only PATH, the output will be both plotted and tabulated path profile data.

PLOT and TABL are keywords applying to the geographical area data in a way functionally similar to the use of PRO and PTAB for path profile data. The desired type(s) of output data for the geographical area are obtained by appropriately specifying LB (for basic transmission loss), PD (for power density), RSL (for received signal level), and/or REL (for communication reliability).

One also may obtain path profile data for the geographical area (that is, MAP has been specified) by specifying PRO = a number and PTAB = a number. Only certain numbers are acceptable as shown in Table 3-1. For example, if profile data are desired for radial paths extending from the transmitter location to the area boundary at uniformly spaced azimuth angle increments of 22.5°, the number 16 must be entered with the keyword, i.e., PRO=16 or PTAB=16.

Table 3-1. Valid Numbers for TABL, PRO, and PTAB (Area Option)

Number Following TABL, PRO, and PTAB	Bearing Angle Increment Between Radials Degrees
0	---
2	180
4	90
8	45
16	22.5
32	11.25
64	5.63
128	2.81
256	1.41
512	0.70
1024	0.35
2048	0.18

<u>Transmitter location</u>. Two keywords provide information on transmitter location. These keywords are XMTRLOC and XMTRCOOR. XMTRLOC is used to define word identification of the transmitter location on the output data simply as a convenience to the user. The information otherwise is not used by the model. XMTRCOOR is used to specify data which define latitude and longitude coordinates for the transmitter. Transmitter location coordinates are required data, and there is no default for this item. When a geographical area is defined, the XMTRCOOR data must be on or within the area boundary.

Receiver location. The keywords defining receiver location are RCVRLOC and RCVRCOOR. RCVRLOC provides word identification of the receiver location on output data as a user convenience. RCVRCOOR is required data which define latitude and longitude coordinates for the receiver. There is no default for this item. However, receiver location data are required and used only when PATH has been specified to obtain path profile data for a specific propagation path.

Frequency. The carrier frequency of a radio transmission must be specified through use of the keyword FREQ. The input specification for carrier frequency must be within the range of 20 MHz to 20,000 MHz. The model contains a default value of 300 MHz.

Transmitter power. A specification of transmitter power - actually power delivered to the input port of the transmitting antenna - is provided by the keyword PWR. Transmitter power may be specified using either watts or decibels referenced to a milliwatt (dBm) as the power units. The model default value is 1 W (30 dBm).

Antenna heights. The structural antenna heights are specified using the keywords HG1 for the transmitting antenna and HG2 for the receiving antenna. These heights may be specified using units of either meters or feet. The default value for each antenna is 10 m.

Antenna gains. The gain of each antenna in the direction of the other antenna (no general antenna gain model is used) is an input to the model. Keywords for the gain of each antenna are G1 for the transmitting antenna and G2 for the receiving antenna. These gain values must be specified in decibels referenced to the gain of an isotropic radiator or receptor (dBi) of electromagnetic energy. Default values are 10 dBi for the transmitting antenna and 0 dBi for the receiving antenna.

Polarization. Polarization of the energy radiated by the transmitting antenna is specified through use of the keyword POL. Either horizontal or vertical polarization may be selected. The default condition assumes horizontal polarization.

Ground description. The model provides two schemes for defining the required ground constants. One scheme allows the user to input a ground descriptor associated with the keyword GND. The choices for ground descriptor are shown in Table 3-2.

Table 3-2. Ground Descriptors and Electrical Constants

Descriptor	GND	Conductivity (S/m)	Dielectric Constant
Good Ground	GOOD	0.02	25
Average Ground	AVG	0.005	15
Poor Ground	POOR	0.001	4
Sea Water	SEA	5	81
Fresh Water	WATER	0.01	81
Concrete	CONCRETE	0.01	5

The second scheme requires the user to define the conductivity using the keyword SGM and the dielectric constant using the keyword EPS. The default condition assumes average ground with SGM = 0.005 S/m and EPS = 15. The allowable ranges are 0 to 100 S/m for conductivity and 1 to 200 for the dielectric constant.

Atmospheric refractivity. Two forms of refractivity data are accepted by the model. The user may specify surface refractivity (N_s) using the keyword NS, or he may specify surface refractivity referenced to mean sea level (N_0, sometimes termed reduced surface refractivity) using the keyword NO. When refractivity referenced to mean sea level is specified, it is converted to a surface refractivity value as described in Appendix C and the propagation loss model references cited earlier in this section.

Climate. An appropriate descriptor for climate in the geographical region containing the communication system(s) being designed or evaluated is specified using the keyword CLIM. The available choices are shown in Table 3-3.

Table 3-3. Climate Descriptors

Equatorial	EQUATOR
Continental Sub-Tropical	CNTROP
Maritime Sub-Tropical	MRTROP
Desert	DESERT
Continental Temperate	CNTEMP
Maritime Temperate, Overland	MRTMPLND
Maritime Temperate, Oversea	MRTMPSEA

The default condition for climate is continental temperate (CNTEMP).

Propagation loss variabilities. There are three contributors to the uncertainty of propagation loss estimates calculated by the point-to-point propagation loss model. (Since basic transmission loss is used in the calculation of power density and received signal level, the variabilities also influence these estimated quantities; see Appendix F.) The first influence considered by the model is that of long-term (greater than one hour) fading, and the terminology usually applied to this variability is time availability, denoted by q_T. Time availability expresses the fraction of time during which hourly median propagation loss will not exceed a given value due to long-term fading effects. The second variability considered is the path-to-path variation in loss. The term applied to this influence is location variability, denoted by q_L. This variability expresses the fraction of similar paths for which propagation loss will not exceed a given value for a specified fraction of the time. The third contribution to variability often is termed the confidence (sometimes prediction error), denoted by the symbol Q. Including the confidence in the model is an acknowledgment of influences which are not included explicitly in time availability and location variability.

This brief background to variabilities affecting propagation loss allows one to realize that each prediction of propagation loss is an estimate of loss which will not be exceeded (for at least) a fraction q_T of the time at a fraction q_L of the locations, estimated with confidence Q. These variabilities are not independent, hence they are specified in sets. The CSPM input data can include up to three such sets of specified variabilities. The keywords assigned to these sets of variabilities are V1, V2, and V3. The model default condition defines one set of variabilities by assuming median values for each parameter of the set, i.e., $q_T = 0.50$, $q_L = 0.50$, and $Q = 0.50$.

Communication reliability output. An output option of the CSPM is plotted and/or tabular data reflecting estimated communication reliability. (See Appendix F for definition and discussion of communication reliability.) Four levels of communication reliability, to be plotted as equal-value contours, may be specified as part of the input data by using the keyword RQ. Any values greater than zero and less than one may be selected. The default condition provides output data for communication reliability values

or 0.10, 0.50, 0.90, and 0.99.

Threshold for received signal level. The concept of communication reliability, identified in the preceding paragraph, makes sense only in the context of communication system performance exceeding some threshold of performance. In the CSPM the index or measure of expected system performance is received signal level. Therefore, when received signal level exceeds some threshold for received signal level (for specified conditions of time availability and location variability), the condition is satisfied with some probability termed communication reliability in this report. A CSPM user either must specify the received signal level threshold for his problem or accept the default value of -88 dBm. The keyword for specifying received signal level threshold is RSLTH.

3.3 Description of Output Data

Output data will describe a single propagation path or a geographical area for which propagation and system performance data are desired. The various possible types of output data were listed in the preceding section: they, also, are shown in Figure 3-1. In this section the data will be described first for a single path, since such data are required for developing basic transmission loss, power density, received signal level, and communication reliability data for a geographical area.

3.3.1 Single Path Data

As has been stated, the propagation path profile, generated by retrieving terrain elevation data from the digitized topographic data file, is available in plotted and tabular forms. These data, showing terrain elevation at points along the path, are calculated at approximately 250 m intervals. At each point along the path, the topographic data which provide elevation at 30 sec intervals in latitude and longitude are bilinearly interpolated to determine path elevation. Figure 3-2 is a typical plotted path profile, and Table 3-4 shows the tabular form of the same path profile data.

One will observe that the abscissa of Figure 3-2 is not linear. Rather, the plot is produced with a curvature which corresponds with the radio ray bending that would occur for the specified atmospheric refractivity. The

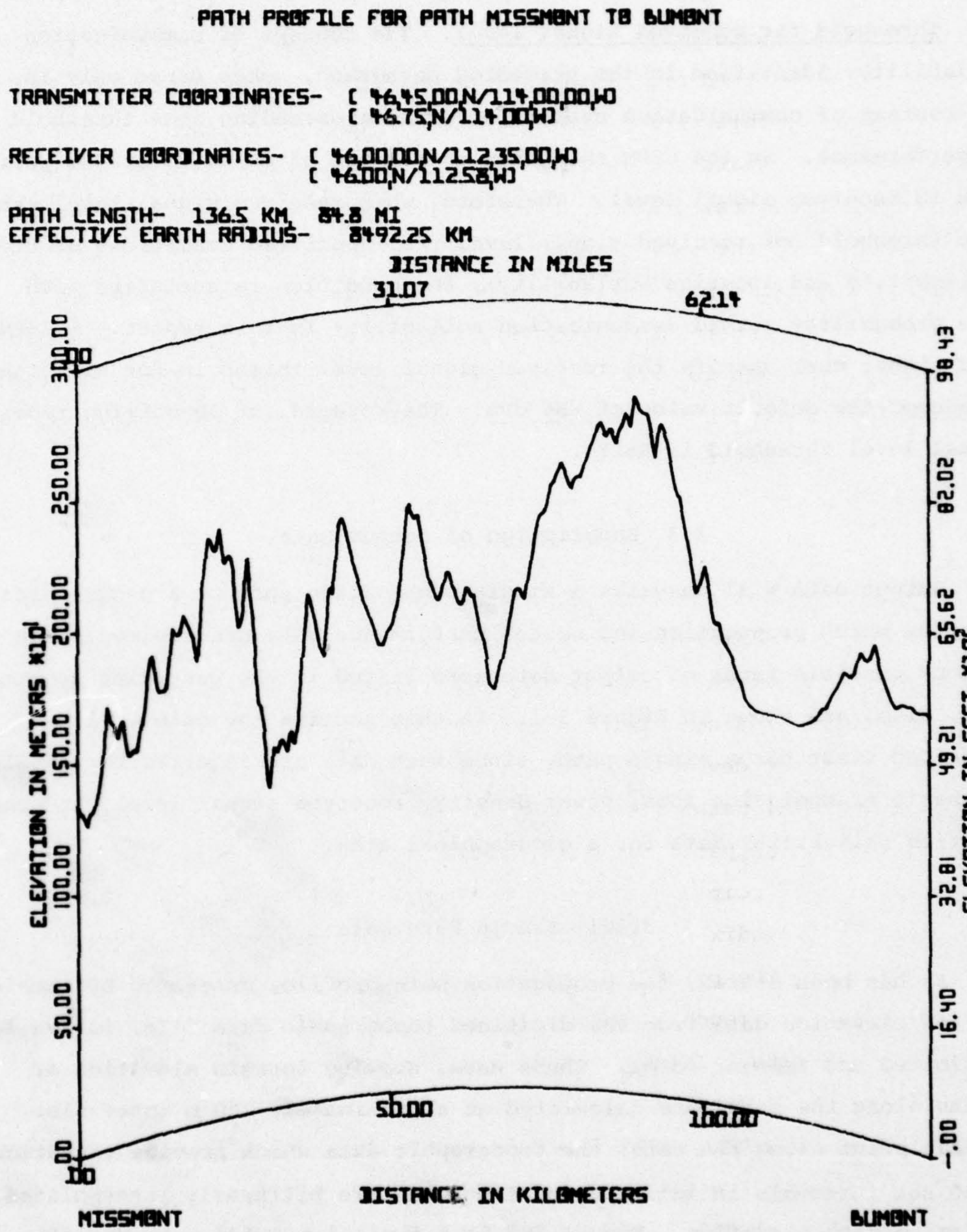

Figure 3-2. Typical path profile plot.

convenience of such a plot is that straight lines can be drawn on the plot to represent the radio rays. For example, the radio horizon and elevation angle can be determined graphically by drawing a straight line from an antenna to the highest visible terrain point in the foreground of that antenna. Another important feature of Figure 3-2 is that the left-hand scale for elevation is in meters, while the right-hand scale is in feet.

As mentioned, the same data in tabular form are shown in Table 3-4. For each path profile point, distance along the geodesic and elevation are presented in both International and English units. Finally, note that information about the path is printed as a heading to the tabulated data. Basic transmission loss for the path follows the tabulated path profile data. This is an optional output features.

3.3.2 Geographical Area Data

The geographical area data, like the path profile data, are produced in plotted and tabular forms. These data reflect basic transmission loss, power density, received signal level, and communication reliability for the geographical area containing a defined transmitter (or receiver) location.

These data are developed by defining a large number of points equally spaced along radial paths extending from the defined location. The angular increment for radial paths has been defined in a way to achieve approximately uniform density of points throughout the geographical area. The reader is referred to Appendix F for definition and discussion of the algorithm used in selecting the points at which calculations are made.

A path profile (such as discussed in the preceding section) is developed for each radial path. These profile data are used to compute the necessary path parameter data used by the Longley-Rice propagation loss model in the point-to-point mode to compute basic transmission loss to each point thus defined. The basic transmission loss data then are used to calculate power density, received signal level, and communication reliability data, discussed in Appendix F.

Plotted output data provide equal-value contours of basic transmission loss, power density, received signal level, or communication reliability. The contour levels for basic transmission loss, power density, and received

Table 3-4. Tabulated Path Profile Data (for Path Profile Shown in Figure 3-2)

```
CSPM OUTPUT DATA FOR SINGLE PATH FROM MISSMONT   TO BUMONT
RUN TITLE:  PATH PROFILE TEST.

TRANSMITTER COORDINATES (XMTRCOOR):  ( 46,45,00,N/114,00,30,W)        RECEIVER COORDINATES (RCVRCOOR):  ( 46,00,00,N/112,35,00,W)
                                     ( 46.75,N/114.00,W)                                                  ( 46.00,N/112.58,W)
TRANSMITTING ANTENNA HEIGHT (HG1):      30.5 M,      100. FT          RECEIVING ANTENNA HEIGHT (HG2):      4.6 M,       15. FT
PATH LENGTH:    136.55 KM,      84.85 MI          INCREMENT SIZE:    249.6 M,       819. FT          NUMBER OF POINTS:   547
TERRAIN IRREGULARITY (DLTH):      951.4 M,     3121. FT               SURFACE REFRACTIVITY (NS):  301.0 N-UNITS
TRANSMITTER SITE ELEVATION ABOVE MSL:     1341.1 M,      4400. FT
TRANSMITTER EFFECTIVE SURFACE ELEVATION ABOVE MSL:     1341.1 M,    4400. FT
TRANSMITTER HORIZON DISTANCE:       4.74 KM,      2.95 MI             TRANSMITTER HORIZON ELEVATION ABOVE MSL:    1683.2 M,      5522. FT
RECEIVER SITE ELEVATION ABOVE MSL:     1676.4 M,      5500. FT
RECEIVER EFFECTIVE SURFACE ELEVATION ABOVE MSL:     1676.4 M,      5500. FT
RECEIVER HORIZON DISTANCE:      8.99 KM,      5.58 MI                 RECEIVER HORIZON ELEVATION ABOVE MSL:    1891.7 M,      6206. FT
```

DIST (KM)	ELEVATION (M)	DIST (MI)	ELEVATION (FT)	DIST (KM)	ELEVATION (M)	DIST (MI)	ELEVATION (FT)
0.00	1341.1	0.00	4400.	.25	1317.3	.16	4322.
.50	1305.9	.31	4284.	.75	1307.0	.47	4288.
1.00	1291.1	.62	4236.	1.25	1271.1	.78	4170.
1.50	1254.2	.93	4115.	1.75	1278.6	1.09	4195.
2.00	1299.4	1.24	4263.	2.25	1301.5	1.40	4270.
2.50	1300.7	1.55	4267.	2.75	1321.5	1.71	4336.
3.00	1339.3	1.86	4394.	3.25	1369.7	2.02	4494.
3.49	1397.9	2.17	4586.	3.74	1432.9	2.33	4701.
3.99	1474.8	2.48	4839.	4.24	1544.6	2.64	5067.
4.49	1625.6	2.79	5333.	4.74	1683.2	2.95	5522.
4.99	1658.6	3.10	5442.	5.24	1624.1	3.26	5328.
5.49	1612.6	3.41	5291.	5.74	1609.2	3.57	5280.
5.99	1586.0	3.72	5203.	6.24	1558.1	3.88	5112.
6.49	1551.8	4.03	5091.	6.74	1590.9	4.19	5220.
6.99	1611.3	4.34	5286.	7.24	1611.1	4.50	5286.
7.49	1559.8	4.65	5117.	7.74	1515.4	4.81	4972.
7.99	1484.9	4.96	4872.	8.24	1471.5	5.12	4828.
8.49	1471.3	5.27	4827.	8.74	1483.5	5.43	4867.
8.99	1488.8	5.58	4884.	9.24	1480.9	5.74	4859.
9.49	1481.9	5.89	4862.	9.74	1508.7	6.05	4950.
9.99	1553.0	6.20	5095.	10.23	1576.7	6.36	5173.
10.48	1586.5	6.51	5205.	10.73	1628.7	6.67	5343.
10.98	1689.1	6.82	5542.	11.23	1753.9	6.98	5754.
11.48	1795.5	7.14	5891.	11.73	1819.3	7.29	5969.
11.98	1826.3	7.45	5992.	12.23	1804.9	7.60	5921.
12.48	1756.9	7.76	5764.	12.73	1705.2	7.91	5594.
12.98	1680.6	8.07	5514.	13.23	1682.8	8.22	5521.
13.48	1683.2	8.38	5522.	13.73	1679.7	8.53	5511.
13.98	1679.3	8.69	5510.	14.23	1692.7	8.84	5553.
14.48	1722.9	9.00	5652.	14.73	1793.5	9.15	5884.
14.98	1860.5	9.31	6104.	15.23	1910.1	9.46	6267.
15.48	1893.3	9.62	6212.	15.73	1884.4	9.77	6182.
15.98	1886.1	9.93	6188.	16.23	1886.5	10.08	6189.
16.48	1897.2	10.24	6225.	16.73	1927.5	10.39	6324.
16.97	1953.3	10.55	6408.	17.22	1939.5	10.70	6363.
17.47	1922.1	10.86	6305.	17.72	1903.0	11.01	6243.

Table 3-4. Continued

DIST (KM)	ELEVATION (M)	DIST (MI)	ELEVATION (FT)	DIST (KM)	ELEVATION (M)	DIST (MI)	ELEVATION (FT)
17.97	1888.9	11.17	6197.	18.22	1872.9	11.32	6145.
18.47	1855.6	11.48	6088.	18.72	1809.5	11.63	5937.
18.97	1778.8	11.79	5836.	19.22	1763.6	11.94	5786.
19.47	1839.3	12.10	6034.	19.72	1944.6	12.25	6380.
19.97	2044.2	12.41	6707.	20.22	2106.3	12.56	6910.
20.47	2151.1	12.72	7057.	20.72	2196.5	12.87	7206.
20.97	2222.5	13.03	7292.	21.22	2215.3	13.18	7268.
21.47	2185.9	13.34	7172.	21.72	2171.8	13.49	7125.
21.97	2170.1	13.65	7120.	22.22	2185.3	13.80	7170.
22.47	2217.3	13.96	7275.	22.72	2246.8	14.12	7371.
22.97	2207.1	14.27	7241.	23.22	2145.0	14.43	7037.
23.47	2114.3	14.58	6937.	23.71	2116.3	14.74	6943.
23.96	2135.0	14.89	7005.	24.21	2140.6	15.05	7023.
24.46	2129.1	15.20	6985.	24.71	2115.9	15.36	6942.
24.96	2079.8	15.51	6823.	25.21	1993.7	15.67	6541.
25.46	1919.4	15.82	6297.	25.71	1857.6	15.98	6094.
25.96	1860.7	16.13	6105.	26.21	1883.3	16.29	6179.
26.46	1908.4	16.44	6261.	26.71	1982.4	16.60	6504.
26.96	2055.1	16.75	6742.	27.21	2114.0	16.91	6936.
27.46	2078.6	17.06	6820.	27.71	1992.2	17.22	6536.
27.96	1912.7	17.37	6275.	28.21	1838.1	17.53	6030.
28.46	1745.8	17.68	5728.	28.71	1629.1	17.84	5345.
28.96	1548.9	17.99	5081.	29.21	1543.4	18.15	5064.
29.46	1520.6	18.30	4989.	29.71	1480.4	18.46	4857.
29.96	1427.3	18.61	4683.	30.20	1341.4	18.77	4401.
30.45	1240.1	18.92	4069.	30.70	1223.6	19.08	4014.
30.95	1259.5	19.23	4132.	31.20	1325.3	19.39	4348.
31.45	1374.3	19.54	4509.	31.70	1368.7	19.70	4490.
31.95	1354.9	19.85	4445.	32.20	1370.6	20.01	4497.
32.45	1394.3	20.16	4574.	32.70	1399.9	20.32	4593.
32.95	1388.5	20.47	4555.	33.20	1372.4	20.63	4503.
33.45	1350.5	20.78	4431.	33.70	1360.7	20.94	4464.
33.95	1413.3	21.10	4637.	34.20	1424.7	21.25	4674.
34.45	1383.6	21.41	4539.	34.70	1376.9	21.56	4517.
34.95	1407.4	21.72	4617.	35.20	1445.0	21.87	4741.
35.45	1487.0	22.03	4879.	35.70	1569.9	22.18	5150.
35.95	1654.6	22.34	5428.	36.20	1737.2	22.49	5699.
36.45	1816.9	22.65	5961.	36.70	1880.9	22.80	6171.
36.94	1934.9	22.96	6348.	37.19	1924.2	23.11	6313.
37.44	1903.0	23.27	6244.	37.69	1872.5	23.42	6143.
37.94	1840.7	23.58	6039.	38.19	1811.7	23.73	5944.
38.44	1771.9	23.89	5813.	38.69	1734.3	24.04	5690.
38.94	1714.3	24.20	5624.	39.19	1701.8	24.35	5583.
39.44	1691.8	24.51	5551.	39.69	1752.0	24.66	5748.
39.94	1829.4	24.82	6002.	40.19	1916.7	24.97	6288.
40.44	1944.9	25.13	6381.	40.69	1947.4	25.28	6389.
40.94	1924.4	25.44	6314.	41.19	1987.2	25.59	6520.
41.44	2067.3	25.75	6782.	41.69	2153.0	25.90	7063.
41.94	2191.6	26.06	7190.	42.19	2201.9	26.21	7224.
42.44	2207.9	26.37	7244.	42.69	2192.3	26.52	7192.
42.94	2163.1	26.68	7097.	43.19	2132.7	26.83	6997.
43.44	2133.9	26.99	6902.	43.68	2079.5	27.14	6822.
43.93	2048.2	27.30	6720.	44.18	2023.1	27.45	6637.
44.43	2006.6	27.61	6583.	44.68	1987.7	27.76	6521.

Table 3-4. Continued

DIST (KM)	ELEVATION (M)	DIST (MI)	ELEVATION (FT)
44.93	1966.2	27.92	6451.
45.43	1923.6	28.23	6311.
45.93	1871.5	28.54	6140.
46.43	1839.8	28.85	6036.
46.93	1810.2	29.16	5939.
47.43	1779.4	29.47	5838.
47.93	1730.8	29.78	5678.
48.43	1708.0	30.09	5604.
48.93	1707.0	30.40	5600.
49.43	1751.0	30.71	5745.
49.93	1766.0	31.02	5794.
50.42	1785.8	31.33	5859.
50.92	1833.8	31.64	6016.
51.42	1878.2	31.95	6162.
51.92	2009.0	32.26	6591.
52.42	2119.4	32.57	6953.
52.92	2227.8	32.88	7309.
53.42	2209.2	33.19	7248.
53.92	2180.9	33.50	7155.
54.42	2192.2	33.81	7192.
54.92	2132.4	34.12	6996.
55.42	2052.4	34.43	6734.
55.92	1981.2	34.74	6500.
56.42	1937.0	35.06	6355.
56.92	1911.9	35.37	6273.
57.41	1872.6	35.68	6144.
57.91	1865.5	35.99	6120.
58.41	1913.3	36.30	6277.
58.91	1948.8	36.61	6394.
59.41	1965.6	36.92	6449.
59.91	1925.4	37.23	6317.
60.41	1893.5	37.54	6212.
60.91	1847.3	37.85	6061.
61.41	1840.6	38.16	6039.
61.91	1866.0	38.47	6122.
62.41	1903.6	38.78	6245.
62.91	1873.0	39.09	6145.
63.41	1878.2	39.40	6162.
63.90	1800.1	39.71	5906.
64.40	1741.7	40.02	5714.
64.90	1706.0	40.33	5597.
65.40	1632.2	40.64	5355.
65.90	1536.7	40.95	5042.
66.40	1520.9	41.26	4990.
66.90	1548.8	41.57	5081.
67.40	1603.6	41.88	5261.
67.90	1648.1	42.19	5407.
68.40	1699.6	42.50	5576.
68.90	1767.2	42.81	5798.
69.40	1830.3	43.12	6005.
69.90	1893.6	43.43	6213.
70.40	1901.1	43.74	6237.
70.89	1887.3	44.05	6192.
71.39	1860.0	44.36	6102.

DIST (KM)	ELEVATION (M)	DIST (MI)	ELEVATION (FT)
45.18	1947.0	28.08	6388.
45.68	1891.9	28.39	6207.
46.18	1856.3	28.70	6090.
46.68	1823.5	29.01	5982.
47.18	1796.7	29.32	5895.
47.68	1754.5	29.63	5756.
48.18	1708.4	29.94	5605.
48.68	1707.1	30.25	5601.
49.18	1729.2	30.56	5673.
49.68	1761.5	30.87	5779.
50.18	1773.5	31.18	5819.
50.67	1802.6	31.49	5914.
51.17	1858.1	31.80	6096.
51.67	1939.3	32.11	6363.
52.17	2076.1	32.42	6811.
52.67	2168.3	32.73	7114.
53.17	2235.3	33.04	7334.
53.67	2189.3	33.35	7183.
54.17	2184.7	33.66	7168.
54.67	2188.3	33.97	7179.
55.17	2087.1	34.28	6847.
55.67	2016.0	34.59	6614.
56.17	1949.5	34.90	6396.
56.67	1925.7	35.21	6318.
57.16	1891.5	35.52	6206.
57.66	1861.3	35.83	6107.
58.16	1889.7	36.14	6200.
58.66	1935.0	36.45	6349.
59.16	1968.2	36.76	6457.
59.66	1943.5	37.07	6376.
60.16	1913.4	37.38	6278.
60.66	1864.9	37.69	6118.
61.16	1840.1	38.00	6037.
61.66	1847.4	38.31	6061.
62.16	1902.0	38.62	6240.
62.66	1891.1	38.93	6204.
63.16	1868.7	39.24	6131.
63.66	1846.9	39.55	6059.
64.15	1764.6	39.86	5789.
64.65	1722.6	40.17	5652.
65.15	1682.3	40.48	5519.
65.65	1580.6	40.79	5186.
66.15	1527.2	41.10	5011.
66.65	1517.7	41.41	4979.
67.15	1579.6	41.72	5182.
67.65	1625.4	42.04	5333.
68.15	1670.9	42.35	5482.
68.65	1734.0	42.66	5689.
69.15	1798.6	42.97	5901.
69.65	1865.0	43.28	6119.
70.15	1899.5	43.59	6232.
70.64	1898.2	43.90	6228.
71.14	1867.8	44.21	6128.
71.64	1896.2	44.52	6221.

Table 3-4. Continued

DIST (KM)	ELEVATION (M)	DIST (MI)	ELEVATION (FT)	DIST (KM)	ELEVATION (M)	DIST (MI)	ELEVATION (FT)
71.89	1931.4	44.67	6336.	72.14	1958.5	44.83	6425.
72.39	1987.0	44.98	6519.	72.64	2027.0	45.14	6650.
72.89	2068.5	45.29	6787.	73.14	2109.1	45.45	6920.
73.39	2133.2	45.60	6999.	73.64	2157.2	45.76	7078.
73.89	2181.3	45.91	7157.	74.14	2183.4	46.07	7163.
74.39	2188.4	46.22	7180.	74.64	2191.7	46.38	7190.
74.89	2206.4	46.53	7239.	75.14	2232.5	46.69	7325.
75.39	2267.4	46.84	7439.	75.64	2295.4	47.00	7531.
75.89	2305.9	47.15	7565.	76.14	2309.9	47.31	7578.
76.39	2324.7	47.46	7627.	76.64	2344.3	47.62	7691.
76.89	2358.3	47.77	7737.	77.14	2367.7	47.93	7768.
77.38	2383.0	48.08	7818.	77.63	2373.3	48.24	7786.
77.88	2358.0	48.39	7736.	78.13	2334.7	48.55	7660.
78.38	2314.1	48.70	7592.	78.63	2297.3	48.86	7537.
78.88	2290.5	49.02	7515.	79.13	2307.9	49.17	7572.
79.38	2322.3	49.33	7619.	79.63	2331.6	49.48	7650.
79.88	2336.1	49.64	7665.	80.13	2337.5	49.79	7669.
80.38	2335.8	49.95	7663.	80.63	2351.9	50.10	7716.
80.88	2369.9	50.26	7775.	81.13	2387.2	50.41	7832.
81.38	2407.2	50.57	7898.	81.63	2425.3	50.72	7957.
81.88	2441.6	50.88	8010.	82.13	2459.3	51.03	8069.
82.38	2476.0	51.19	8123.	82.63	2490.7	51.34	8172.
82.88	2506.3	51.50	8223.	83.13	2524.0	51.65	8281.
83.38	2542.4	51.81	8341.	83.63	2547.5	51.96	8358.
83.88	2536.8	52.12	8323.	84.12	2519.2	52.27	8265.
84.37	2497.4	52.43	8194.	84.62	2497.2	52.58	8193.
84.87	2513.8	52.74	8238.	85.12	2525.1	52.89	8285.
85.37	2525.4	53.05	8285.	85.62	2509.6	53.20	8233.
85.87	2478.2	53.36	8130.	86.12	2472.9	53.51	8113.
86.37	2493.8	53.67	8182.	86.62	2524.1	53.82	8281.
86.87	2535.1	53.98	8317.	87.12	2540.8	54.13	8336.
87.37	2563.3	54.29	8410.	87.62	2587.3	54.44	8489.
87.87	2580.1	54.60	8465.	88.12	2564.7	54.75	8414.
88.37	2542.8	54.91	8342.	88.62	2574.8	55.06	8447.
88.87	2612.4	55.22	8571.	89.12	2655.6	55.37	8713.
89.37	2646.7	55.53	8683.	89.62	2632.2	55.68	8636.
89.87	2611.8	55.84	8569.	90.12	2601.3	56.00	8534.
90.37	2597.3	56.15	8521.	90.61	2595.8	56.31	8516.
90.86	2595.0	56.46	8514.	91.11	2593.3	56.62	8508.
91.36	2575.4	56.77	8449.	91.61	2553.4	56.93	8377.
91.86	2497.9	57.08	8195.	92.11	2458.0	57.24	8064.
92.36	2433.7	57.39	7984.	92.61	2475.3	57.55	8121.
92.86	2514.7	57.70	8250.	93.11	2556.0	57.86	8386.
93.36	2561.5	58.01	8404.	93.61	2550.8	58.17	8369.
93.86	2536.3	58.32	8321.	94.11	2516.5	58.48	8256.
94.36	2490.8	58.63	8172.	94.61	2463.9	58.79	8084.
94.86	2431.8	58.94	7978.	95.11	2393.6	59.10	7853.
95.36	2360.4	59.25	7744.	95.61	2331.5	59.41	7649.
95.86	2306.4	59.56	7567.	96.11	2293.8	59.72	7526.
96.36	2293.7	59.87	7525.	96.61	2254.1	60.03	7395.
96.86	2219.4	60.18	7282.	97.11	2175.5	60.34	7138.
97.35	2150.0	60.49	7054.	97.60	2124.6	60.65	6971.
97.85	2091.1	60.80	6861.	98.10	2048.7	60.96	6721.
98.35	2006.4	61.11	6583.	98.60	1969.0	61.27	6460.

Table 3-4. Continued

DIST (KM)	ELEVATION (M)	DIST (MI)	ELEVATION (FT)	DIST (KM)	ELEVATION (M)	DIST (MI)	ELEVATION (FT)
98.85	1936.5	61.42	6353.	99.10	1943.5	61.58	6376.
99.35	1958.0	61.73	6424.	99.60	1980.0	61.89	6496.
99.85	2000.5	62.04	6563.	100.10	2030.9	62.20	6663.
100.35	2044.5	62.35	6708.	100.60	2024.9	62.51	6643.
100.85	1988.9	62.67	6525.	101.10	1944.8	62.82	6381.
101.35	1896.9	62.98	6224.	101.60	1856.5	63.13	6091.
101.85	1833.0	63.29	6014.	102.10	1829.9	63.44	6003.
102.35	1837.9	63.60	6030.	102.60	1830.9	63.75	6007.
102.85	1806.9	63.91	5928.	103.10	1771.4	64.06	5812.
103.35	1760.2	64.22	5775.	103.60	1758.7	64.37	5770.
103.85	1746.9	64.53	5731.	104.09	1736.3	64.68	5697.
104.34	1728.2	64.84	5670.	104.59	1717.0	64.99	5633.
104.84	1699.6	65.15	5576.	105.09	1681.4	65.30	5516.
105.34	1660.5	65.46	5448.	105.59	1640.6	65.61	5382.
105.84	1630.0	65.77	5348.	106.09	1624.0	65.92	5328.
106.34	1600.1	66.08	5250.	106.59	1575.4	66.23	5169.
106.84	1556.7	66.39	5107.	107.09	1549.3	66.54	5083.
107.34	1542.6	66.70	5061.	107.59	1536.5	66.85	5041.
107.84	1533.1	67.01	5030.	108.09	1529.3	67.16	5017.
108.34	1525.5	67.32	5005.	108.59	1524.0	67.47	5000.
108.84	1524.0	67.63	5000.	109.09	1524.0	67.78	5000.
109.34	1523.3	67.94	4998.	109.59	1522.0	68.09	4993.
109.84	1521.3	68.25	4991.	110.09	1521.3	68.40	4991.
110.34	1522.3	68.56	4994.	110.59	1523.3	68.71	4998.
110.83	1524.0	68.87	5000.	111.08	1524.0	69.02	5000.
111.33	1524.0	69.18	5000.	111.58	1524.0	69.33	5000.
111.83	1523.6	69.49	4999.	112.08	1523.6	69.65	4999.
112.33	1524.0	69.80	5000.	112.58	1523.0	69.96	4997.
112.83	1521.1	70.11	4991.	113.08	1519.2	70.27	4984.
113.33	1517.2	70.42	4978.	113.58	1515.1	70.58	4971.
113.83	1513.5	70.73	4966.	114.08	1511.6	70.89	4959.
114.33	1509.7	71.04	4953.	114.58	1507.9	71.20	4947.
114.83	1506.0	71.35	4941.	115.08	1505.5	71.51	4939.
115.33	1505.8	71.66	4940.	115.58	1506.7	71.82	4943.
115.83	1509.9	71.97	4954.	116.08	1513.5	72.13	4965.
116.33	1516.5	72.28	4975.	116.58	1520.1	72.44	4987.
116.83	1523.3	72.59	4998.	117.08	1526.4	72.75	5008.
117.33	1530.1	72.90	5020.	117.57	1537.5	73.06	5044.
117.82	1542.9	73.21	5062.	118.07	1546.5	73.37	5074.
118.32	1555.7	73.52	5104.	118.57	1567.6	73.68	5143.
118.82	1578.4	73.83	5179.	119.07	1588.1	73.99	5210.
119.32	1593.3	74.14	5227.	119.57	1593.5	74.30	5228.
119.82	1597.0	74.45	5240.	120.07	1613.3	74.61	5293.
120.32	1629.1	74.76	5345.	120.57	1643.0	74.92	5390.
120.82	1655.0	75.07	5430.	121.07	1665.1	75.23	5463.
121.32	1673.3	75.38	5491.	121.57	1686.7	75.54	5534.
121.82	1698.9	75.69	5574.	122.07	1709.9	75.85	5610.
122.32	1728.0	76.00	5669.	122.57	1742.8	76.16	5718.
122.82	1753.2	76.31	5752.	123.07	1749.6	76.47	5740.
123.32	1742.5	76.63	5717.	123.57	1737.4	76.78	5700.
123.82	1739.7	76.94	5708.	124.07	1748.6	77.09	5737.
124.31	1757.6	77.25	5766.	124.56	1780.0	77.40	5840.
124.81	1810.1	77.56	5939.	125.06	1831.5	77.71	6009.
125.31	1843.5	77.87	6048.	125.56	1836.0	78.02	6024.

Table 3-4. Continued

DIST (KM)	ELEVATION (M)	DIST (MI)	ELEVATION (FT)
125.81	1827.9	78.18	5997.
126.31	1819.7	78.49	5970.
126.81	1833.5	78.80	6015.
127.31	1879.0	79.11	6165.
127.81	1877.6	79.42	6160.
128.31	1816.8	79.73	5961.
128.81	1777.5	80.04	5832.
129.31	1753.8	80.35	5754.
129.81	1715.4	80.66	5628.
130.31	1693.7	80.97	5557.
130.81	1670.5	81.28	5481.
131.30	1676.6	81.59	5501.
131.80	1688.2	81.90	5539.
132.30	1691.6	82.21	5550.
132.80	1687.8	82.52	5537.
133.30	1695.3	82.83	5562.
133.80	1684.9	83.14	5523.
134.30	1675.9	83.45	5498.
134.80	1677.0	83.76	5502.
135.30	1681.9	84.07	5518.
135.80	1685.8	84.38	5531.
136.30	1679.5	84.69	5510.

DIST (KM)	ELEVATION (M)	DIST (MI)	ELEVATION (FT)
126.06	1818.7	78.33	5967.
126.56	1825.3	78.64	5989.
127.06	1854.8	78.95	6085.
127.56	1891.7	79.26	6206.
128.06	1844.4	79.57	6051.
128.56	1795.0	79.88	5889.
129.06	1763.7	80.19	5786.
129.56	1732.2	80.50	5683.
130.06	1704.2	80.81	5591.
130.56	1680.3	81.12	5513.
131.05	1670.8	81.43	5482.
131.55	1682.4	81.74	5520.
132.05	1692.8	82.05	5554.
132.55	1687.7	82.36	5537.
133.05	1690.3	82.67	5545.
133.55	1692.1	82.98	5552.
134.05	1678.2	83.29	5506.
134.55	1676.1	83.61	5499.
135.05	1679.3	83.92	5510.
135.55	1684.4	84.23	5526.
136.05	1682.6	84.54	5520.
136.55	1676.4	84.85	5500.

signal level are selected to span the minimum-value-to-maximum-value interval using up to ten subintervals. Figure 3-3 is a typical plot of contour data. Four user-selected values of communication reliability are contoured when that option is selected.

Tabulated output data provide the calculated values of basic transmission loss, power density, received signal level, and communication reliability at points spaced 1 km apart along selected, uniformly spaced radials. Table 3-5 is a typical example of tabulated data. This form of output data can become voluminous, consequently the user is cautioned to not specify needlessly large numbers of radials for tabular data.

3.4 Limitations of the Model

The CSPM has been designed with the fewest possible constraints, so that a broad, general utility can be realized. Several of the model limitations are imposed by the propagation loss model. These limitations include:

--Carrier frequencies between 20 and 20,000 MHz.

--Antenna heights between 0.5 and 3000 m.

--Vertical or horizontal polarization for radiated energy.

In addition, the following constraints have been programmed into the model:

--A maximum of three sets of variabilities (for time availability, location variability, and confidence) for each analysis run.

--A maximum of four levels of communication reliability plotted per run.

--A maximum geographical area of 2° latitude by 2° longitude for contoured output data.

Finally, the topographic data impose a restriction on the model's capability to consider the fine-grain character of the terrain, since granularity of the digitized topographic data is 30" in latitude and longitude and precision of the associated elevation values is 20 ft (6.1 m).

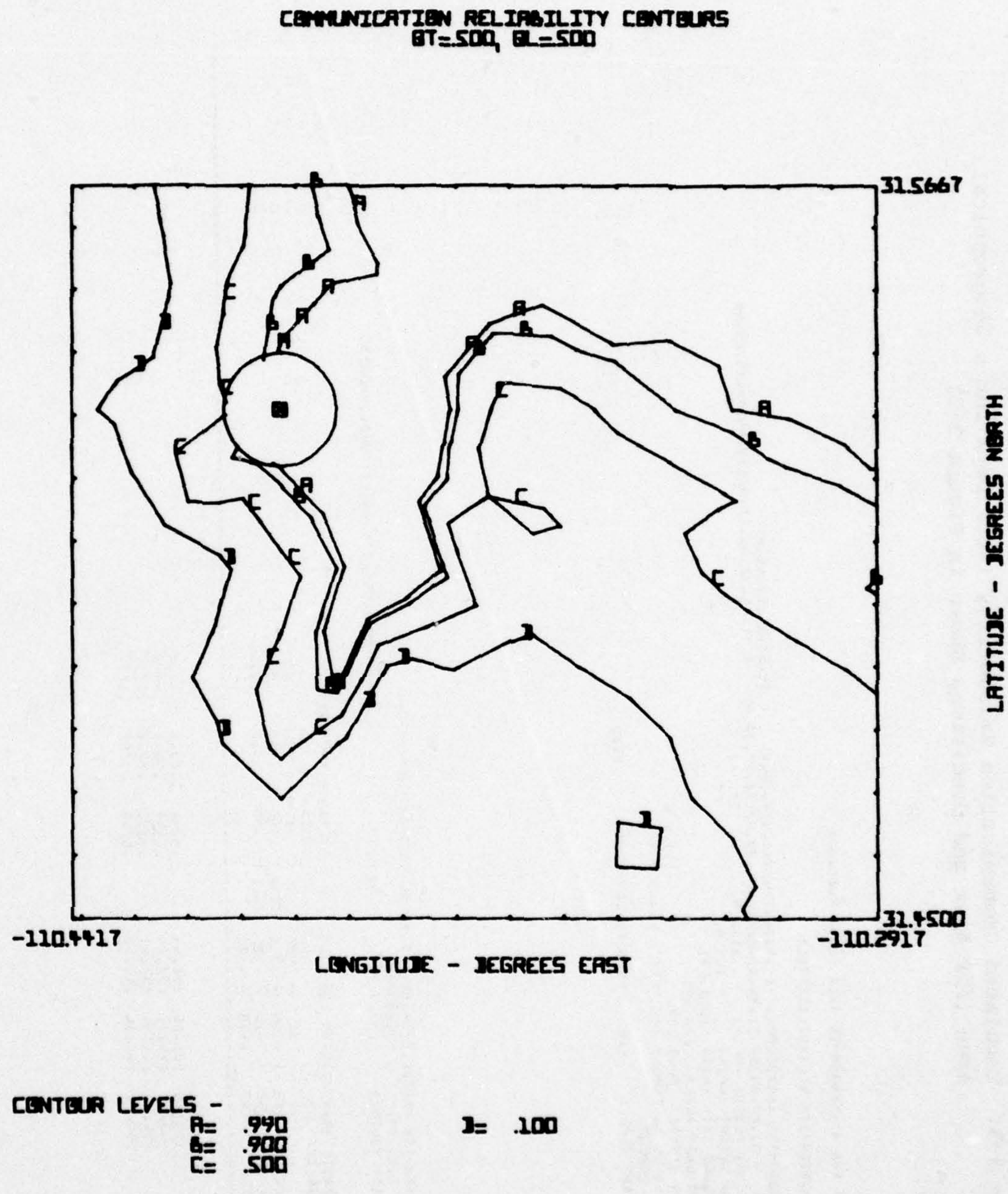

Figure 3-3. Contoured communication reliability (REL) data throughout a geographical area. Contour levels are REL = 0.99, 0.90, 0.50, and 0.10 for conditions of time availability = 0.50 and location variability = 0.50.

Table 3-5. Tabulated Communication Reliability (REL) Data for a Geographical Area (for Area and Conditions Shown in Figure 3-3)

CSPM OUTPUT DATA FOR A GEOGRAPHIC AREA ABOUT HUACHUCA

RUN TITLE: COMMUNICATION RELIABILITY TEST

TRANSMITTER COORDINATES (XMTRCOOR): (31.31.51.N/110.24.10.W) (31.53.N/110.40.W)
MAP AREA BOUNDS: (31.27.00.N/ 31.34.00.N/110.26.30.W/110.17.30.W) (31.45.N/ 31.57.N/110.44.W/110.29.W)
TRANSMITTING ANTENNA HEIGHT (HG1): 10.0 M. 33. FT
RECEIVING ANTENNA HEIGHT (HG2): 1.8 M. 6. FT
TRANSMITTING ANTENNA GAIN (G1): 10.0 DBI
RECEIVING ANTENNA GAIN (G2): 0.0 DBI
TRANSMITTER POWER (PWR): 50.0 DBM. 100.0 W
RECEIVED SIGNAL LEVEL THRESHOLD (RSLTH): -83.5 DBM
CLIMATE (CLIM): CNTEMP
DIELECTRIC CONSTANT (EPS): 4.0 CONDUCTIVITY (SGM): .0010

CSPM EVALUATION DATA FOR RADIAL BEARING 0.00 DEGREES CW FROM NORTH.
PATH LENGTH: 3.99 KM. 2.48 MI
TERRAIN IRREGULARITY (DLTH): 297.7 M. 977. FT SURFACE REFRACTIVITY (NS): 301.0N-UNITS

			BASIC TRANSMISSION LOSS (LB) UNITS: DB				RELIABILITY (REL) UNITS: Q		
			V1	V2	V3		V1	V2	V3
DISTANCE		(QT)	.950	.950	.500	(QT)	.950	.950	.500
		(QL)	.950	.500	.500	(QL)	.950	.500	.500
KM	MI	(Q)	.500	.500	.500				
1.00	.62		115.48	101.56	101.56		.3998	1.0000	1.0000
2.00	1.24		143.51	129.31	129.29		.4995	.9640	.9642
3.00	1.86		154.49	140.05	140.02		.0802	.6700	.6716
4.00	2.49		154.70	140.06	140.00		.0750	.6707	.6735

Table 3-5. Continued

CSPM EVALUATION DATA FOR RADIAL BEARING 45.00 DEGREES CW FROM NORTH.
PATH LENGTH: 5.64 KM. 3.51 MI
TERRAIN IRREGULARITY (DLTH): 371.6 M. 1219. FT SURFACE REFRACTIVITY (NS): 301.0N-UNITS

DISTANCE			BASIC TRANSMISSION LOSS (LB) UNITS: DB				RELIABILITY (REL) UNITS: Q		
			V1	V2	V3		V1	V2	V3
		(QT)	.950	.950	.500	(QT)	.950	.950	.500
		(QL)	.950	.500	.500	(QL)	.950	.500	.500
KM	MI	(Q)	.500	.500	.500				
1.00	.62		106.92	92.56	92.56		1.0000	1.0000	1.0000
2.00	1.24		113.86	99.26	99.26		.9999	1.0000	1.0000
3.00	1.86		118.19	103.39	103.38		.9993	1.0000	1.0000
4.00	2.49		121.35	106.39	106.37		.9975	1.0000	1.0000
5.00	3.11		123.83	108.72	108.70		.9939	1.0000	1.0000
6.00	3.73		125.93	110.71	110.67		.9875	1.0000	1.0000

CSPM EVALUATION DATA FOR RADIAL BEARING 90.00 DEGREES CW FROM NORTH.
PATH LENGTH: 10.54 KM. 6.55 MI
TERRAIN IRREGULARITY (DLTH): 451.6 M. 1482. FT SURFACE REFRACTIVITY (NS): 301.0N-UNITS

DISTANCE			BASIC TRANSMISSION LOSS (LB) UNITS: DB				RELIABILITY (REL) UNITS: Q		
			V1	V2	V3		V1	V2	V3
		(QT)	.950	.950	.500	(QT)	.950	.950	.500
		(QL)	.950	.500	.500	(QL)	.950	.500	.500
KM	MI	(Q)	.500	.500	.500				
1.00	.62		107.87	93.18	93.18		1.0000	1.0000	1.0000
2.00	1.24		114.34	100.04	100.03		.9998	1.0000	1.0000
3.00	1.86		119.58	104.51	104.49		.9988	1.0000	1.0000
4.00	2.49		159.36	144.15	144.13		.0218	.4668	.4679
5.00	3.11		160.39	145.06	145.03		.0155	.4211	.4228
6.00	3.73		153.72	138.29	138.24		.0951	.7481	.7501
7.00	4.35		147.64	132.12	132.05		.2972	.9285	.9297
8.00	4.97		140.43	124.84	124.75		.6541	.9921	.9923
9.00	5.59		133.08	117.42	117.30		.9119	.9996	.9997
10.00	6.21		132.66	116.95	116.85		.9195	.9997	.9997
11.00	6.84		133.71	117.94	117.83		.8979	.9995	.9996

Table 3-5. Continued

CSPM EVALUATION DATA FOR RADIAL BEARING 135.00 DEGREES CW FROM NORTH.
PATH LENGTH: 12.72 KM. 7.90 MI
TERRAIN IRREGULARITY (DLTH): 760.8 M. 2496. FT SURFACE REFRACTIVITY (NS): 301.0N-UNITS

DISTANCE			BASIC TRANSMISSION LOSS (LB) UNITS: DB				RELIABILITY (REL) UNITS: Q		
			V1	V2	V3		V1	V2	V3
		(QT)	.950	.950	.500	(QT)	.950	.950	.500
		(QL)	.950	.500	.500	(QL)	.950	.500	.500
KM	MI	(Q)	.500	.500	.500				
1.00	.62		110.39	95.03	95.03		1.0000	1.0000	1.0000
2.00	1.24		117.42	101.93	101.92		.9995	1.0000	1.0000
3.00	1.86		116.43	100.83	100.82		.9997	1.0000	1.0000
4.00	2.49		139.46	123.76	123.74		.6968	.9940	.9941
5.00	3.11		158.23	142.47	142.41		.0293	.5528	.5557
6.00	3.73		178.88	163.05	162.97		.0000	.0058	.0060
7.00	4.35		178.92	162.94	162.82		.0000	.0058	.0061
8.00	4.97		178.56	162.63	162.49		.0000	.0063	.0067
9.00	5.59		175.61	159.64	159.45		.0000	.0172	.0183
10.00	6.21		173.11	157.11	156.88		.0000	.0366	.0391
11.00	6.84		172.31	156.28	156.00		.0001	.0454	.0490
12.00	7.46		167.72	151.65	151.43		.0007	.1416	.1483
13.00	8.08		167.68	151.59	151.31		.0007	.1421	.1505

Table 3-5. Continued

CSPM EVALUATION DATA FOR RADIAL BEARING 180.00 DEGREES CW FROM NORTH.
PATH LENGTH: 9.00 KM, 5.59 MI
TERRAIN IRREGULARITY (DLTH): 749.4 M, 2459. FT SURFACE REFRACTIVITY (NS): 301.0N-UNITS

DISTANCE			BASIC TRANSMISSION LOSS (LB) UNITS: DB				RELIABILITY (REL) UNITS: Q		
			V1	V2	V3		V1	V2	V3
		(QT)	.950	.950	.500	(QT)	.950	.950	.500
		(QL)	.950	.500	.500	(QL)	.950	.500	.500
KM	MI	(Q)	.500	.500	.500				
1.00	.62		107.44	92.10	92.10		1.0000	1.0000	1.0000
2.00	1.24		154.84	139.36	139.35		.0752	.7001	.7008
3.00	1.86		163.86	148.27	148.24		.0047	.2711	.2726
4.00	2.49		157.01	141.33	141.29		.0422	.6093	.6110
5.00	3.11		157.10	141.34	141.24		.0392	.6100	.6150
6.00	3.73		155.98	140.16	140.10		.0547	.6661	.6686
7.00	4.35		176.86	160.99	160.79		.0000	.0109	.0116
8.00	4.97		181.62	165.70	165.44		.0000	.0017	.0019
9.00	5.59		184.50	168.84	168.51		.0000	.0004	.0004

CSPM EVALUATION DATA FOR RADIAL BEARING 225.00 DEGREES CW FROM NORTH.
PATH LENGTH: 5.22 KM, 3.24 MI
TERRAIN IRREGULARITY (DLTH): 632.7 M, 2076. FT SURFACE REFRACTIVITY (NS): 301.0N-UNITS

DISTANCE			BASIC TRANSMISSION LOSS (LB) UNITS: DB				RELIABILITY (REL) UNITS: Q		
			V1	V2	V3		V1	V2	V3
		(QT)	.950	.950	.500	(QT)	.950	.950	.500
		(QL)	.950	.500	.500	(QL)	.950	.500	.500
KM	MI	(Q)	.500	.500	.500				
1.00	.62		145.55	130.39	130.39		.3983	.9505	.9506
2.00	1.24		154.47	139.16	139.14		.0821	.7091	.7098
3.00	1.86		176.74	161.30	161.26		.0000	.0115	.0117
4.00	2.49		181.19	165.64	165.58		.0000	.0022	.0023
5.00	3.11		184.07	168.44	168.34		.0000	.0006	.0006
6.00	3.73		186.00	170.29	170.15		.0000	.0002	.0003

Table 3-5. Continued

CSPM EVALUATION DATA FOR RADIAL BEARING 270.00 DEGREES CW FROM NORTH.
PATH LENGTH: 3.69 KM, 2.29 MI
TERRAIN IRREGULARITY (DLTH): 497.0 M, 1630. FT SURFACE REFRACTIVITY (NS): 301.0N-UNITS

DISTANCE			BASIC TRANSMISSION LOSS (LB) UNITS: DB				RELIABILITY (REL) UNITS: Q		
			V1	V2	V3		V1	V2	V3
		(QT)	.950	.950	.500	(QT)	.950	.950	.500
		(QL)	.950	.500	.500	(QL)	.950	.500	.500
KM	MI	(Q)	.500	.500	.500				
1.00	.62		156.89	142.05	142.05		.0459	.5723	.5725
2.00	1.24		165.03	150.00	149.99		.0032	.2048	.2053
3.00	1.86		163.29	148.11	148.09		.0059	.2788	.2798
4.00	2.49		174.00	158.68	158.62		.0000	.0254	.0259

CSPM EVALUATION DATA FOR RADIAL BEARING 315.00 DEGREES CW FROM NORTH.
PATH LENGTH: 5.22 KM, 3.24 MI
TERRAIN IRREGULARITY (DLTH): 499.2 M, 1638. FT SURFACE REFRACTIVITY (NS): 301.0N-UNITS

DISTANCE			BASIC TRANSMISSION LOSS (LB) UNITS: DB				RELIABILITY (REL) UNITS: Q		
			V1	V2	V3		V1	V2	V3
		(QT)	.950	.950	.500	(QT)	.950	.950	.500
		(QL)	.950	.500	.500	(QL)	.950	.500	.500
KM	MI	(Q)	.500	.500	.500				
1.00	.62		150.69	135.85	135.85		.1825	.8322	.8323
2.00	1.24		161.88	146.84	146.83		.0099	.3357	.3365
3.00	1.86		172.40	157.21	157.17		.0001	.0400	.0404
4.00	2.49		172.20	156.88	156.82		.0001	.0427	.0434
5.00	3.11		175.46	160.33	159.93		.0000	.0162	.0167
6.00	3.73		178.33	162.80	162.66		.0000	.0059	.0063

4. SUMMARY OF MODEL FEATURES AND OUTPUT OPTIONS

1. A computer-based method has been developed which uses a point-to-point propagation loss model to evaluate communication system performance within a defined geographical area. In addition, propagation path characteristics for specific paths can be obtained from the model.
2. The model is user-oriented, which means that input information may be supplied in free format, and various options are allowed for describing and specifying the input characteristics and data.
3. The model provides a capability for plotting equal-value contours over a geographical area. The data which may be plotted include basic transmission loss, power density, received signal level, and communication reliability. Tabulated output data also may be specified for each output.
4. The model includes a file of digitized topographic characteristics for the contiguous United States. Terrain elevation data are retrieved from this file and used in developing required input data for the point-to-point propagation loss model.
5. The model is structured so as to facilitate the use of additional and/or improved data as they become available. This feature is particularly important when considering the use of an improved propagation loss model, new or improved terrain data which would provide greater detail in describing the topography of an area, new statistical characterizations within the model, and new indices (or measures) of satisfactory system performance.
6. The model is capable of very general application and utility. Limitations of the model are those imposed by the propagation loss model, the granularity of the topographic data, and practical restrictions arbitrarily programmed into the model to maintain reasonable limits on the volume of output data.
7. The propagation loss model calculates basic transmission loss as a random function of time and space by modeling atmospheric, climate, and terrain irregularity influences upon propagation. The model is good for frequencies between 20 and 20,000 MHz.

5. RECOMMENDATIONS

Although the capability provided by the Communication System Performance Model is a valuable addition to the automated design evaluation aids available to a communication system engineer, to further improve and extend the usefulness of the CSPM, it is recommended that:

1. The feasibility be studied for adapting the CSPM for interactive operation from a remote terminal.
2. The influence of rainfall upon radio signal attenuation be incorporated into the statistics of the point-to-point propagation loss model used by the CSPM.
3. An improved terrain characteristics data base be added to the model, so that considerably greater detail of the terrain characteristics and man-made obstructions can be considered in generating the propagation path profiles used by the point-to-point propagation loss model.
4. A revised point-to-point propagation loss model be used to replace the Longley-Rice Model, used in the point-to-point mode in the present CSPM.
5. A map of surface refractivity referenced to mean sea level (NO) be developed for the CSPM.

Recommendation three may involve handling much larger files of terrain information than the present data base requires. It may be necessary, therefore, to consider use of some mass storage medium other than magnetic tape--for example, permanent disc pack. Similarly, recommendation one could involve requirements for a callable storage medium other than magnetic tape, if magnetic tape calls from a remote terminal are not allowed.

6. ACKNOWLEDGMENTS

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7. REFERENCES

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APPENDIX A. USER'S GUIDE

COMMUNICATION SYSTEM PERFORMANCE MODEL

This appendix describes how to use the Communication System Performance Model (CSPM) on a CDC 6000 series computer system. The model has been designed with free-format input and mnemonic keywords to aid the user in describing the system to be analyzed in familiar engineering terms. Options are available to select the type of output desired, as well as to describe the characteristics of the geographical area and communication system being studied. A run title card is required as the first of the data cards. Following the title card, the CSPM input data may be given in any order on the subsequent data cards. If more than one item of input data is specified per card, commas must be used as separators. Blanks always are ignored except on the title card. Error messages or warning diagnostics are issued if conflicting options are selected, if an option is specified more than once, or if values selected for a parameter are out of range for the model. Default values have been included in the model for all parameters except the transmitter and receiver coordinates.

The CSPM may be used in two different modes - for a single path or for an area defined around the transmitter. For either mode, the user may select output options that produce plotted path profiles, tabulated path profile data, and a tabulated summary of basic transmission loss for the path or area. When the analysis is done for an area, contour plots of basic transmission loss, power density, received signal level, and communication reliability over the desired area are available. It also is possible to have tabular printed summaries of each type of output data throughout the area. The single path mode is selected by the keyword PATH; the geographical area mode is selected by MAP. No specification of mode results in the default condition which is MAP. A list of the options that a user may select, appropriate to each mode, is given below. Examples of CSPM input and output follow later in this appendix.

A.1 Single Path Mode

As discussed, specifying the keyword PATH selects the single path mode of the CSPM. Input data pertinent to this mode are:

XMTRLOC and RCVRLOC

These optional keywords allow the user to specify an alphanumeric name of up to 10 characters to be associated with the transmitter and receiver locations on the plotted and tabulated output.

PRO and PTAB

The keyword PRO indicates plotted path profile data are desired. The keyword PTAB indicates tabulated path profile data are desired. In the single path mode, the default condition provides both forms of output. To select one, but not the other, the user should include the desired keyword in his input data. This selection will cause the other option to be defaulted off. An alternative specification for either option is PRO=0 or PTAB=0 which means that the indicated form of output will not be provided.

LB

The user may request that basic transmission loss for the path be printed by including this keyword. In the single path mode, the default condition is no basic transmission loss calculation. If LB is selected, then the user also may enter any values that he desires for FREQ, POL, HG1, HG2, CLIM, GND, or EPS/SGM, NS or NO, and the variabilities V1, V2, or V3. Otherwise, the CSPM default values will be used. Please refer to the next section of this appendix for discussion of these parameters.

A.2 Geographical Area Mode

Specifying the keyword MAP selects the mode of the CSPM that analyzes communication system performance over an area around the transmitter coordinates. If only the keyword MAP is specified or if the default option is desired, the area to be analyzed is defined as a 1° by 1° "box" with boundaries formed by the latitude and longitude values 0.5° in each direction from the transmitter coordinates. When a particular area is desired (the transmitter may be located anywhere within the area), the user must specify MAP followed by two latitude values and two longitude values which define the area boundaries, i.e., MAP = (31,27,00,N/31,34,00,N/110,26,30,W/ 110,17,30,W). The two latitudes are given first, and the values are in positive degrees, minutes, and seconds with the hemisphere given as N or S and the longitude

with respect to the Prime Meridian given as E or W. In all cases, the area must lie within the bounds of the data available in the topographic data base, which is an area from 23° to 51° N latitude and from 60° to 130° W longitude. Other input data generally applicable to the area mode of model operation are:

PLOT and TABL

The keyword PLOT indicates that plotted (contoured) output is desired. The keyword TABL indicates that tabulated output describing basic transmission loss, power density, received signal level, or communication reliability is described. The default condition is PLOT. A contour plot will be produced for each type of data selected (LB, PD, RSL, and REL) and for each set of variabilities (V1, V2, and V3) that was specified in the input data for this run. If no plots are desired, specify PLOT=0. When TABL is specified, the tabulated data will be provided only for selected radials extending at equal-value bearing angle increments from the transmitting antenna location throughout the area. A separate column is produced for each type of data for each selected variability set (V1, V2, and V3). The radial paths are selected by a number following the keyword, i.e., TABL=32. The only acceptable numbers are powers of two. Table A-1 shows the acceptable numbers and the bearing angle increment between radials that are realized for each number. When a number is used which is not a power of two, the next lower value corresponding to a power of two will be used. The default condition for TABL is 16. The model user is cautioned to consider carefully the value used with TABL, for the output could become voluminous for large numbers.

PRO and PTAB

These keywords are valid for the area mode of operation as well as for the single path mode, and the same meaning accompanies each keyword. However, the plotted or tabulated path profile data will be provided only for selected radial paths designated by a number following the keyword as discussed for TABL. The same numbers are valid as for TABL, but the default value for PRO and PTAB is eight. In the area mode of operation, no path profile data will be output unless the specification PRO=n or PTAB=n is given, where n denotes a number.

The same rule discussed for TABL for values other than powers of two is followed by PRO and PTAB.

Table A-1. Valid Numbers for TABL, PRO, and PTAB (Area Option)

Number Following TABL, PRO, and PTAB	Bearing Angle Increment Between Radials Degrees
0	----
2	180
4	90
8	45
16	22.5
32	11.25
64	5.63
128	2.81
256	1.41
512	0.70
1024	0.35
2048	0.18

LB, PD, RSL, and REL

These keywords define the CSPM outputs of basic transmission loss (LB), power density (PD), received signal level (RSL), and communication reliability (REL), throughout the geographical area which may be specified by the model user. Since basic transmission loss is required for calculation of each of the other type of output, LB is the default type of output data. Any combination including all four types of output may be specified. Basic transmission loss (LB) always is tabulated when TABL is specified.

Discussion of the remaining input data pertinent to the area mode is organized to present first the input required to calculate basic transmission loss. The additional input used to calculate power density is presented next, followed by the additional data required to calculate received signal level, and finally the additional input required for calculating communication reliability is discussed.

A.2.1 Input Required for Basic Transmission Loss (LB)

XMTRCOOR

Coordinates of the transmitter (actually the transmitting antenna) location are required input; there is no default. XMTRCOOR is used to specify the latitude and longitude of the transmitter in positive degrees, minutes, and seconds. The latitude must be given first followed by N or S, and the latitude must be followed by E or W, i.e., XMTRCOOR=(31,31,51,N/110,24,10,W). The transmitter coordinates must be within or on the boundaries defined by deyword MAP.

XMTRLOC

This optional keyword may be used to assign an alphanumeric name of up to 10 characters to the transmitter location, i.e., XMTRLOC=HUACHUCA. This provision is simply a user convenience for quick identification of plotted and printed output.

FREQ

The transmitter radio frequency in megahertz is specified using this keyword, i.e., FREQ=237.865 MHz. Limits for the specification of frequency are 20 to 20,000 MHz. The default for frequency is 300 MHz. Any value within the above limits and up to 10 characters (including a decimal point) in length is accepted by the model. Printed summaries of the input will show values to four decimal places.

POL

Polarization of the radiated energy may be specified using the keyword POL. The options are horizontal, POL=H, and vertical, POL=V, polarization. The default condition is horizontal polarization.

HG1 and HG2

These keywords are used to specify antenna heights above ground for the transmitter (HG1) and receiver (HG2). Heights may be specified in either meters or feet, i.e., HG1=15.3 M or HG2=12.6 FT. When units (M or FT) are not included in the specification, meters are assumed. Valid limits for either antenna height are 0.5 to 3000 m (1.64 to 9843 ft). The default for each height is 10 m. Values within the above limits up to 10 characters (including the decimal point) in length are accepted by the model. Printed summaries of the input will show values to one decimal place for meters and to units for feet.

CLIM

Selection of a climate code describing the geographical area of interest is allowed through use of this keyword, i.e., CLIM=CNTEMP. The choices are shown in Table A-2 where a descriptive word or phrase is keyed to a single keyword descriptor to be used with CLIM. The default condition is continental temperate climate.

Table A-2. Climate Descriptors

Climate Keyword	Climate Descriptor
EQUATOR	Equatorial
CNTROP	Continental Sub-Tropical
MRTROP	Maritime Sub-Tropical
DESERT	Desert
CNTEMP	Continental Temperate
MRTMLND	Maritime Temperate, Overland
MRTMSEA	Maritime Temperate, Oversea

EPS and SGM or GND

The ground dielectric constant and conductivity may be specified by using keywords EPS and SGM, respectively, i.e., EPS=11.9 and SGM=0.0385. Valid limits for the dielectric constant (EPS) are 1 to 200. Valid limits for conductivity (SGM) are 0 to 100 S/m. Values within the above limits up to 10 characters (including the decimal point) in length for each variable are accepted by the model. Printed summaries of the input will show the dielectric constant to one decimal place and the conductivity to four decimal places. An alternative to specifying EPS and SGM is the specification of a ground descriptor using the keyword GND, i.e., GND=POOR. Table A-3 shows the acceptable ground descriptors and keywords with associated values for dielectric constant and conductivity. The default condition is average ground.

Table A-3. Ground Descriptors and Electrical Constants

Ground Keyword	Ground Descriptor	SGM (S/m)	EPS
GOOD	Good Ground	0.02	25
AVG	Average Ground	0.005	15
POOR	Poor Ground	0.001	4
SEA	Sea Water	5	81
WATER	Fresh Water	0.01	81
CONCRETE	Concrete	0.01	5

NS or NO

Surface refractivity denoted by the keyword NS or surface refractivity referenced to mean sea level (reduced surface refractivity) denoted by NO may be specified, i.e., NS=327 or NO=289. Valid limits for each variable are 250 to 400 N-units. The default value is 301 N-units which corresponds to the common assumption of effective earth radius equal to 4/3 actual earth radius. Printed summaries will show the value to one decimal place. When surface refractivity (NS) values are not known for the area of interest, the model user may wish to use reduced surface refractivity (NO) values from world maps of that parameter. Such maps are available from the International Radio Consultative Committee (CCIR, 1974) or in the NBS Monograph by Bean et al (1960).

V1, V2, and V3

The time variability, location variability, and prediction confidence to be used in calculating basic transmission loss are specified as a variability set, i.e., V1=(.99,.95,.90). Time variability always relates to the first value in the set, location variability related to the second value, and prediction confidence relates to the third value. Up to three such sets may be specified per run. Values must be between .001 and .999. If a 0 is specified, it will be changed to .001, and 1 will be changed to .999. The default condition is one variability set using median values. If a value is omitted from a set, the corresponding value from the last set (or the default in the case of V1) will be used. For example: V1 = (.2,.3), V2 = (,,.9) would result in V1 = (.2, .3,.5), and V2 = (.2,.3,.9) being read.

(Calculations for communication reliability as an output use only the first two values from each variability set.)

A.2.2. Additional Input Required for Power Density (PD)

All input discussed in the preceding parts of Section A.2 is used in the calculation of power density.* In addition, the following input items also are used.

PWR

The specification of transmitter output power in watts (W) or decibels referenced to a milliwatt (dBm) is provided using the keyword PWR, i.e., PWR=100 W or PWR=30. When no units (W or dBm) are specified, decibels referenced to a milliwatt are assumed. Limits for specification of transmitter power are 0 to 120 dBm or 0.001 to 1×10^9 W. The default value is 30 dBm. Any value within the above limits up to 10 characters (including the decimal point) in length is accepted by the model; however, printed summaries of the input will show values to one decimal place.

G1

Transmitting antenna gain in the direction of the receiving antenna may be specified in decibels referenced to an isotropic antenna (dBi) using this keyword, i.e., G1=23. Limits for specifying the transmitting antenna gain are 0 to 100 dBi. Any value within these limits up to 10 characters (including the decimal point) in length is accepted by the model. Printed summaries of the input will show the value to one decimal place. The default value for the transmitting antenna gain is 10 dBi.

A.2.3. Additional Input Required for Received Signal Level (RSL)

All input discussed thus far in Section A.2 is used in the calculation of received signal level. In addition, the following input item also is used.

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*As shown in Appendix F (F-3), power density is independent of frequency. However, the model calculations of power density are made using basic transmission loss data computed earlier in the program execution. Frequency dependence is removed as shown in (F-4).

G2

Receiving antenna gain in the direction of the transmitting antenna may be specified in decibels referenced to an isotropic antenna (dBi) using this keyword, i.e., G2=6. The same limits and discussion of values presented in the preceding section for the transmitting antenna gain apply. The default value for the receiving antenna gain is 0 dBi.

A.2.4. Additional Input Required for Communication Reliability (REL)

All input discussed in section A.2 is used in the calculation of communication reliability. The following input items are added to those items already discussed.

RSLTH

The threshold for received signal level--a satisfactory system performance criterion--may be specified in decibels referenced to a milliwatt using this keyword, i.e., RSLTH=-83. Limits for specifying the received signal level threshold are -200 and +50 dBm. Any value within these limits up to 10 characters (including the decimal point) in length is acceptable to the model, but printed summaries of the input will show the value to one decimal place. The default for received signal level threshold is -88 dBm.

RQ

Up to four contour levels for plotting communication reliability may be specified using this keyword, i.e., RQ=(.99,.95,.90,.50). Values must be between 0.001 and 0.999; however, zero will be changed to 0.001 and one will be changed to 0.999. The default values for communication reliability are .99,.90,.50, and .10. If a value is omitted by leaving its space vacant, the default value is used. For example: RQ = (.2,,.6) would be read as RQ = (.2,.95,.6).

A.3 Sample Input and Output

The input and output for three sample applications are presented in this section as further aid to users of the CSPM. The first sample application is use of the model to generate a single path profile and to calculate basic transmission loss for the path. The second sample illustrates use

of the CSPM to produce plotted and tabulated output of received signal level throughout a geographical area. The third sample application illustrates plotted communication reliability for the same area, but some different input values are used.

Input data (provided by the user) for the single path are as follows, where each line contains one item of input: PATH PROFILE TEST (Run title which may contain up to 60 characters).

XMTRCOOR = (31,31,51,N/110,24,10,W)

XMTRLOC = HUACHUCA

RCVRCOOR = (32,12,38,N/110,58,31,W)

RCVRLOC = TUCSON

PRO

LB

FREQ = 376.125

HG1 = 30 FT

HG2 = 75 FT

CLIM = CNTEMP

NO = 290

V1 = (.9,.9,.9)

Note that POL and GND (or EPS and SGM) have not been specified; hence, the model will use default conditions for these items. The default conditions are POL=H and GND=AVG (EPS=0.005 and SGM=15). The printed input summary is shown in Table A-4, and Figure A-1 is the output path profile.

Input data (provided by the user) to obtain plotted and tabulated output indicating received signal level throughout a geographical area are as follows, where each line contains one item of input:

RECEIVED SIGNAL LEVEL TEST (Run title--up to 60 characters)

MAP = (31,27.00,N/31,34,00,N/110,26,30,W/110,17,30,W)

PLOT

TABL = 8

RSL

XMTRCOOR = (31,31,51,N/110,24,10,W)

XMTRLOC = HUACHUCA

FREQ = 394.675

POL = V

Table A-4. Printed Summary of Output Data for Single Path Profile

CSPM OUTPUT DATA FOR SINGLE PATH FROM HUACHUCA TO TUCSON
RUN TITLE: PATH PROFILE TEST.

TRANSMITTER COORDINATES (XMTRCOOR): (31,31,51,N/110,24,10,W) (31.53,N/110.40,W)
RECEIVER COORDINATES (RCVRCOOR): (32,12,38,N/110,58,31,W) (32.21,N/110.98,W)
TRANSMITTING ANTENNA HEIGHT (HG1): 9.1 M, 30. FT
RECEIVING ANTENNA HEIGHT (HG2): 22.9 M, 75. FT
PATH LENGTH: 93.14 KM, 57.88 MI
INCREMENT SIZE: 249.7 M, 819. FT
NUMBER OF POINTS: 373
TERRAIN IRREGULARITY (DLTH): 341.7 M, 1121. FT
SURFACE REFRACTIVITY (NS): 250.3 N-UNITS
TRANSMITTER SITE ELEVATION ABOVE MSL: 2015.3 M, 6612. FT
TRANSMITTER EFFECTIVE SURFACE ELEVATION ABOVE MSL: 2015.3 M, 6612. FT
TRANSMITTER HORIZON DISTANCE: .50 KM, .31 MI
TRANSMITTER HORIZON ELEVATION ABOVE MSL: 2070.7 M, 6794. FT
RECEIVER SITE ELEVATION ABOVE MSL: 731.5 M, 2400. FT
RECEIVER EFFECTIVE SURFACE ELEVATION ABOVE MSL: 731.5 M, 2400. FT
RECEIVER HORIZON DISTANCE: 43.45 KM, 27.00 MI
RECEIVER HORIZON ELEVATION ABOVE MSL: 1603.0 M, 5259. FT

DIST (KM)	ELEVATION (M)	DIST (MI)	ELEVATION (FT)	DIST (KM)	ELEVATION (M)	DIST (MI)	ELEVATION (FT)
0.00	2015.3	0.00	6612.	.25	2047.4	.16	6717.
.50	2070.7	.31	6794.	.75	2091.0	.47	6860.
1.00	2087.4	.62	6848.	1.25	2052.8	.78	6735.
1.50	2027.7	.93	6652.	1.75	1972.3	1.09	6471.
2.00	1922.4	1.24	6307.	2.25	1877.8	1.40	6161.
2.50	1812.5	1.55	5947.	2.75	1756.6	1.71	5763.
3.00	1712.3	1.86	5618.	3.25	1672.0	2.02	5485.
3.50	1635.6	2.17	5366.	3.75	1621.0	2.33	5318.
4.00	1615.9	2.48	5301.	4.25	1603.7	2.64	5262.
4.49	1584.7	2.79	5199.	4.74	1558.9	2.95	5114.
4.99	1535.4	3.10	5037.	5.24	1533.5	3.26	5031.
5.49	1531.1	3.41	5023.	5.74	1528.2	3.57	5014.
5.99	1524.9	3.72	5003.	6.24	1516.9	3.88	4977.
6.49	1507.8	4.03	4947.	6.74	1499.3	4.19	4919.
6.99	1491.3	4.34	4893.	7.24	1484.5	4.50	4870.
7.49	1480.4	4.65	4857.	7.74	1475.5	4.81	4941.
7.99	1469.6	4.97	4821.	8.24	1464.7	5.12	4805.
8.49	1461.4	5.28	4795.	8.74	1458.7	5.43	4786.
8.99	1456.1	5.59	4777.	9.24	1454.8	5.74	4773.
9.49	1454.8	5.90	4773.	9.74	1454.4	6.05	4772.
9.99	1455.0	6.21	4774.	10.24	1456.6	6.36	4779.
10.49	1457.6	6.52	4782.	10.74	1454.0	6.67	4770.
10.99	1448.0	6.83	4751.	11.24	1442.5	6.98	4733.
11.49	1437.5	7.14	4716.	11.74	1433.0	7.29	4702.
11.99	1429.2	7.45	4689.	12.24	1426.4	7.60	4680.
12.49	1424.6	7.76	4674.	12.74	1423.7	7.91	4671.
12.99	1424.4	8.07	4673.	13.23	1426.4	8.22	4680.
13.48	1428.5	8.38	4687.	13.73	1430.5	8.53	4693.
13.98	1432.5	8.69	4700.	14.23	1437.9	8.84	4718.
14.48	1443.6	9.00	4736.	14.73	1448.9	9.15	4754.
14.98	1453.4	9.31	4770.	15.23	1457.9	9.47	4783.
15.48	1460.4	9.62	4791.	15.73	1462.4	9.78	4798.
15.98	1463.0	9.93	4800.	16.23	1463.0	10.09	4800.
16.48	1463.0	10.24	4800.	16.73	1463.0	10.40	4800.
16.98	1463.0	10.55	4800.	17.23	1463.0	10.71	4800.
17.48	1463.1	10.86	4800.	17.73	1464.7	11.02	4805.

Table A-4. Continued

DIST (KM)	ELEVATION (M)	DIST (MI)	ELEVATION (FT)	DIST (KM)	ELEVATION (M)	DIST (MI)	ELEVATION (FT)
17.98	1465.2	11.17	4807.	18.23	1464.8	11.33	4806.
18.48	1463.4	11.48	4801.	18.73	1464.1	11.64	4803.
18.98	1465.6	11.79	4809.	19.23	1466.2	11.95	4810.
19.48	1465.8	12.10	4809.	19.73	1464.4	12.26	4805.
19.98	1465.3	12.41	4807.	20.23	1466.8	12.57	4812.
20.48	1467.4	12.72	4814.	20.73	1467.0	12.88	4813.
20.98	1465.6	13.03	4808.	21.23	1463.2	13.19	4801.
21.48	1463.0	13.34	4800.	21.73	1463.0	13.50	4800.
21.97	1463.0	13.65	4800.	22.22	1465.3	13.81	4807.
22.47	1467.9	13.96	4816.	22.72	1469.7	14.12	4822.
22.97	1470.3	14.28	4824.	23.22	1469.6	14.43	4822.
23.47	1467.4	14.59	4814.	23.72	1465.1	14.74	4807.
23.97	1463.0	14.90	4800.	24.22	1463.0	15.05	4800.
24.47	1463.0	15.21	4800.	24.72	1463.0	15.36	4800.
24.97	1463.0	15.52	4800.	25.22	1463.0	15.67	4800.
25.47	1463.0	15.83	4800.	25.72	1463.0	15.98	4800.
25.97	1463.0	16.14	4800.	26.22	1463.0	16.29	4800.
26.47	1463.0	16.45	4800.	26.72	1460.2	16.60	4791.
26.97	1451.3	16.76	4762.	27.22	1441.9	16.91	4731.
27.47	1432.1	17.07	4698.	27.72	1421.7	17.22	4664.
27.97	1414.4	17.38	4641.	28.22	1410.4	17.53	4627.
28.47	1407.7	17.69	4618.	28.72	1405.5	17.84	4611.
28.97	1403.8	18.00	4606.	29.22	1402.6	18.15	4602.
29.47	1402.1	18.31	4600.	29.72	1402.1	18.46	4600.
29.97	1402.1	18.62	4600.	30.22	1402.1	18.77	4600.
30.47	1402.1	18.93	4600.	30.71	1402.1	19.09	4600.
30.96	1401.2	19.24	4597.	31.21	1399.5	19.40	4591.
31.46	1395.7	19.55	4579.	31.71	1391.9	19.71	4567.
31.96	1389.1	19.86	4554.	32.21	1384.9	20.02	4544.
32.46	1382.2	20.17	4535.	32.71	1379.6	20.33	4526.
32.96	1376.9	20.48	4517.	33.21	1374.2	20.64	4509.
33.46	1371.7	20.79	4500.	33.71	1371.8	20.95	4501.
33.96	1372.9	21.10	4504.	34.21	1375.0	21.26	4511.
34.46	1378.1	21.41	4521.	34.71	1382.1	21.57	4535.
34.96	1385.9	21.72	4547.	35.21	1389.3	21.88	4558.
35.46	1392.7	22.03	4569.	35.71	1396.1	22.19	4580.
35.96	1399.4	22.34	4591.	36.21	1402.1	22.50	4600.
36.46	1402.1	22.65	4600.	36.71	1402.1	22.81	4600.
36.96	1402.3	22.96	4601.	37.21	1403.4	23.12	4604.
37.46	1405.0	23.27	4610.	37.71	1410.1	23.43	4626.
37.96	1417.4	23.59	4650.	38.21	1421.8	23.74	4665.
38.46	1423.9	23.90	4672.	38.71	1425.0	24.05	4675.
38.96	1426.3	24.21	4679.	39.21	1431.6	24.36	4697.
39.45	1442.3	24.52	4732.	39.70	1451.1	24.67	4761.
39.95	1457.9	24.83	4783.	40.20	1462.7	24.98	4799.
40.45	1459.3	25.14	4788.	40.70	1453.3	25.29	4768.
40.95	1447.7	25.45	4750.	41.20	1442.6	25.60	4733.
41.45	1438.1	25.76	4718.	41.70	1429.3	25.91	4689.
41.95	1424.3	26.07	4673.	42.20	1427.2	26.22	4683.
42.45	1438.0	26.38	4718.	42.70	1443.0	26.53	4734.
42.95	1424.4	26.69	4673.	43.20	1392.6	26.84	4569.
43.45	1365.8	27.00	4481.	43.70	1343.8	27.15	4409.
43.95	1343.1	27.31	4407.	44.20	1342.3	27.46	4404.
44.45	1346.3	27.62	4416.	44.70	1354.9	27.77	4445.

Table A-4. Continued

DIST (KM)	ELEVATION (M)	DIST (MI)	ELEVATION (FT)	DIST (KM)	ELEVATION (M)	DIST (MI)	ELEVATION (FT)
44.95	1363.3	27.93	4473.	45.20	1364.6	28.08	4477.
45.45	1361.9	28.24	4469.	45.70	1355.2	28.40	4446.
45.95	1349.9	28.55	4429.	46.20	1351.0	28.71	4432.
46.45	1351.4	28.86	4434.	46.70	1349.9	29.02	4429.
46.95	1346.4	29.17	4417.	47.20	1350.1	29.33	4430.
47.45	1363.1	29.48	4472.	47.70	1375.1	29.64	4511.
47.95	1386.0	29.79	4547.	48.19	1396.1	29.95	4580.
48.44	1407.4	30.10	4617.	48.69	1432.7	30.26	4700.
48.94	1472.7	30.41	4832.	49.19	1527.5	30.57	5011.
49.44	1597.0	30.72	5239.	49.69	1603.0	30.88	5259.
49.94	1569.9	31.03	5150.	50.19	1544.9	31.19	5069.
50.44	1531.9	31.34	5026.	50.69	1530.0	31.50	5020.
50.94	1526.6	31.65	5009.	51.19	1518.0	31.81	4980.
51.44	1500.1	31.96	4922.	51.69	1471.3	32.12	4827.
51.94	1443.6	32.27	4736.	52.19	1416.8	32.43	4648.
52.44	1389.9	32.58	4560.	52.69	1366.7	32.74	4484.
52.94	1347.9	32.89	4422.	53.19	1337.6	33.05	4389.
53.44	1318.6	33.21	4326.	53.69	1290.7	33.36	4234.
53.94	1258.8	33.52	4130.	54.19	1240.7	33.67	4071.
54.44	1233.1	33.83	4045.	54.69	1231.4	33.98	4040.
54.94	1235.6	34.14	4054.	55.19	1237.7	34.29	4061.
55.44	1203.0	34.45	3947.	55.69	1171.3	34.60	3843.
55.94	1142.5	34.76	3748.	56.19	1116.7	34.91	3664.
56.44	1098.1	35.07	3603.	56.69	1091.1	35.22	3580.
56.93	1085.4	35.38	3561.	57.18	1079.2	35.53	3541.
57.43	1072.5	35.69	3519.	57.68	1064.9	35.84	3494.
57.93	1057.5	36.00	3469.	58.18	1050.3	36.15	3446.
58.43	1044.6	36.31	3427.	58.68	1038.9	36.46	3409.
58.93	1031.3	36.62	3383.	59.18	1023.7	36.77	3359.
59.43	1015.8	36.93	3333.	59.68	1008.4	37.08	3309.
59.93	1003.2	37.24	3291.	60.18	998.3	37.39	3275.
60.43	993.3	37.55	3259.	60.68	988.4	37.71	3243.
60.93	983.6	37.86	3227.	61.18	979.4	38.02	3213.
61.43	975.6	38.17	3201.	61.68	972.4	38.33	3190.
61.93	969.5	38.48	3181.	62.18	964.1	38.64	3163.
62.43	958.7	38.79	3145.	62.68	953.8	38.95	3129.
62.93	949.5	39.10	3115.	63.18	945.6	39.26	3102.
63.43	942.2	39.41	3091.	63.68	939.3	39.57	3082.
63.93	936.8	39.72	3074.	64.18	934.9	39.88	3067.
64.43	951.3	40.03	3121.	64.68	952.0	40.19	3123.
64.93	944.2	40.34	3098.	65.18	935.9	40.50	3070.
65.43	927.1	40.65	3042.	65.67	919.8	40.81	3018.
65.92	913.0	40.96	2995.	66.17	909.3	41.12	2983.
66.42	906.9	41.27	2975.	66.67	904.7	41.43	2968.
66.92	902.2	41.58	2960.	67.17	899.8	41.74	2952.
67.42	897.3	41.89	2944.	67.67	894.8	42.05	2936.
67.92	893.5	42.20	2931.	68.17	892.4	42.36	2928.
68.42	891.2	42.52	2924.	68.67	890.1	42.67	2920.
68.92	888.7	42.83	2916.	69.17	886.8	42.98	2909.
69.42	885.4	43.14	2905.	69.67	884.4	43.29	2902.
69.92	884.0	43.45	2900.	70.17	882.5	43.60	2895.
70.42	880.0	43.76	2887.	70.67	877.6	43.91	2879.
70.92	875.1	44.07	2871.	71.17	872.8	44.22	2864.
71.42	871.7	44.38	2860.	71.67	870.6	44.53	2856.

Table A-4. Continued

DIST (KM)	ELEVATION (M)	DIST (MI)	ELEVATION (FT)	DIST (KM)	ELEVATION (M)	DIST (MI)	ELEVATION (FT)
71.92	869.4	44.69	2852.	72.17	868.3	44.84	2849.
72.42	866.5	45.00	2843.	72.67	864.0	45.15	2835.
72.92	861.3	45.31	2826.	73.17	858.7	45.46	2817.
73.42	856.6	45.62	2810.	73.67	855.5	45.77	2807.
73.92	854.4	45.93	2803.	74.17	853.4	46.08	2800.
74.41	853.4	46.24	2800.	74.66	853.4	46.39	2800.
74.91	853.4	46.55	2800.	75.16	853.4	46.70	2800.
75.41	853.4	46.86	2800.	75.66	852.6	47.01	2797.
75.91	850.7	47.17	2791.	76.16	849.2	47.33	2786.
76.41	848.1	47.48	2782.	76.66	847.5	47.64	2780.
76.91	846.7	47.79	2778.	77.16	844.6	47.95	2771.
77.41	843.0	48.10	2766.	77.66	841.9	48.26	2762.
77.91	841.3	48.41	2760.	78.16	840.4	48.57	2757.
78.41	841.0	48.72	2759.	78.66	842.0	48.88	2762.
78.91	842.9	49.03	2765.	79.16	843.8	49.19	2768.
79.41	844.7	49.34	2771.	79.66	843.5	49.50	2767.
79.91	839.9	49.65	2756.	80.16	836.3	49.81	2744.
80.41	832.9	49.96	2732.	80.66	829.2	50.12	2720.
80.91	825.6	50.27	2709.	81.16	822.0	50.43	2697.
81.41	818.4	50.58	2685.	81.66	815.6	50.74	2676.
81.91	813.2	50.89	2668.	82.16	811.4	51.05	2662.
82.41	809.5	51.20	2656.	82.66	806.6	51.36	2646.
82.91	803.1	51.51	2635.	83.15	799.5	51.67	2623.
83.40	795.9	51.83	2611.	83.65	792.5	51.98	2600.
83.90	791.2	52.14	2596.	84.15	790.0	52.29	2592.
84.40	788.9	52.45	2588.	84.65	787.8	52.60	2585.
84.90	786.4	52.76	2580.	85.15	783.9	52.91	2572.
85.40	781.4	53.07	2564.	85.65	779.0	53.22	2556.
85.90	776.5	53.38	2548.	86.15	774.8	53.53	2542.
86.40	774.1	53.69	2540.	86.65	773.3	53.84	2537.
86.90	772.1	54.00	2533.	87.15	770.4	54.15	2528.
87.40	769.0	54.31	2523.	87.65	768.2	54.46	2520.
87.90	767.4	54.62	2518.	88.15	766.2	54.77	2514.
88.40	764.5	54.93	2508.	88.65	763.2	55.08	2504.
88.90	762.3	55.24	2501.	89.15	761.5	55.39	2498.
89.40	760.4	55.55	2495.	89.65	756.7	55.70	2483.
89.90	752.9	55.86	2470.	90.15	749.1	56.01	2458.
90.40	745.4	56.17	2446.	90.65	743.6	56.32	2440.
90.90	743.0	56.49	2438.	91.15	741.9	56.64	2434.
91.40	740.4	56.79	2429.	91.65	738.3	56.95	2422.
91.89	736.0	57.10	2415.	92.14	734.1	57.26	2409.
92.39	732.8	57.41	2404.	92.64	731.9	57.57	2401.
92.89	731.5	57.72	2400.	93.14	731.5	57.88	2400.

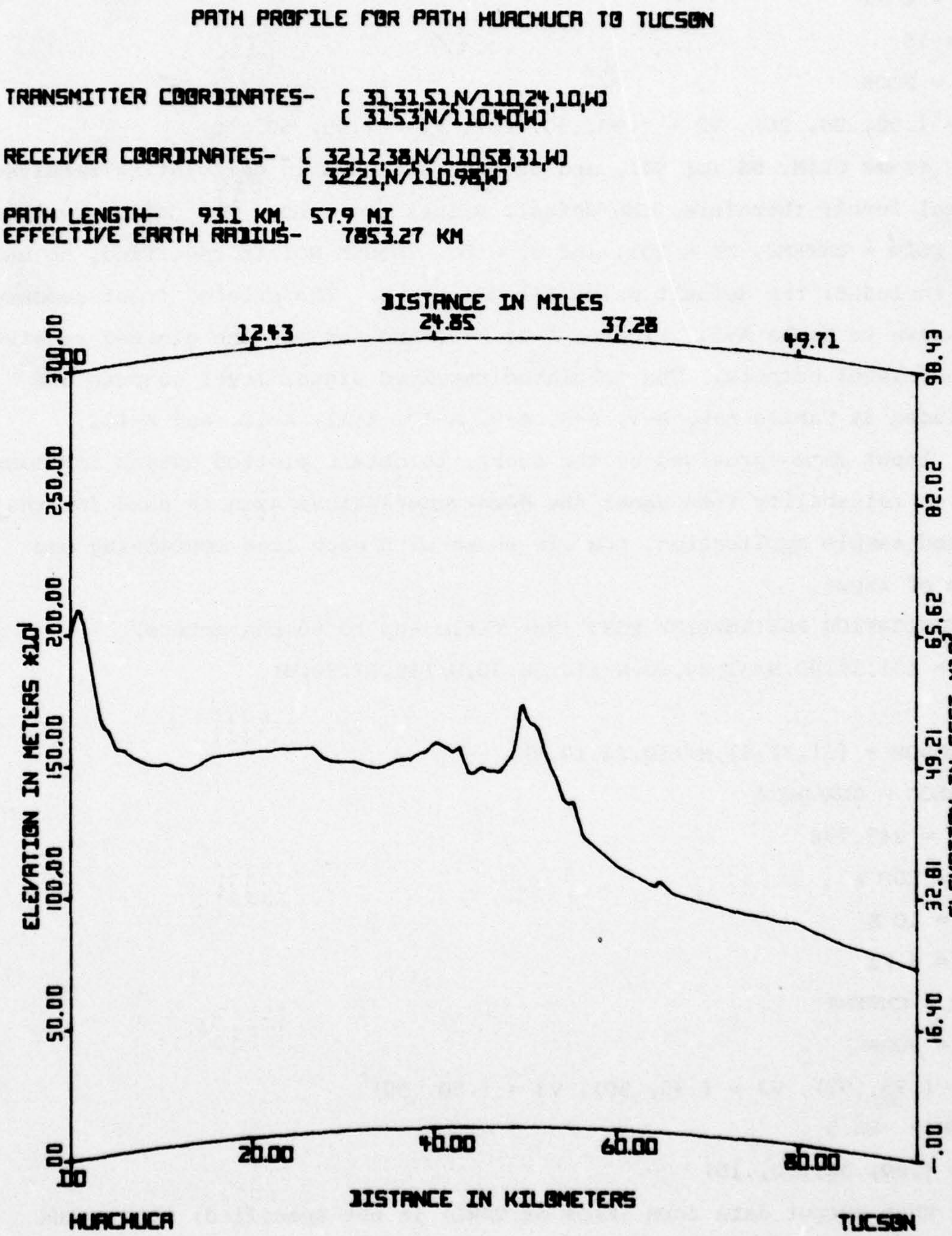

Figure A-1. Path profile, Ft. Huachuca to Tucson, with calculated basic transmission loss. Typical application of the CSPM in single path mode.

PWR = 100 W

HG1 = 20

HG2 = 6 FT

G1 = 15

GND = POOR

V1 = (.90,.90,.90), V2 = (.90,.90,.50), V3 = (.90,.50,.50)

Items CLIM, NS (or NO), and G2 also are used in calculating received signal level; therefore, the default values are used. The default values are CLIM = CNTEMP, NS = 301, and G2 = 0. Though HG1 is specified, no units are included; the default units for HG1 are M. The printed input summary is shown in Table A-5. Figures A-2, A-2, and A-4 are the plotted received signal level outputs. The tabulated received signal level outputs are included as Tables A-6, A-7, A-8, A-9, A-10, A-11, A-12, and A-13.

Input data (provided by the user), to obtain plotted output for communication reliability throughout the same geographical area as used for the second sample application, now are shown with each line containing one item of input.

COMMUNICATION RELIABILITY TEST (Run title--up to 60 characters)

MAP = (31,27,00,N/31,34,00,N/110,26,30,W/110,17,30,W)

REL

XMTRCOOR = (31,31,51,N/110,24,10,W)

XMTRLOC = HUACHUCA

FREQ = 245.798

PWR = 100 W

HG1 = 10 M

HG2 = 6 FT

CLIM = CNTEMP

GND = POOR

V1 = (.95,.95), V2 = (.95,.50), V3 = (.50,.50)

RSLTH = -83.5

RQ = (.99,.90,.50,.10)

Note that output data form (PLOT or TABL) is not specified; this means that the default provision will be invoked which provides only plotted output for the geographical area mode of operation. Also, it will be observed that POL, G1, and G2 are not specified. The default values that

Table A-5. Printed Summary of Input Data for Received Signal Level Output

```
CSPM INPUT DATA SUMMARY

TITLE:  RECEIVED SIGNAL LEVEL TEST
CARRIER FREQUENCY (FREQ):      394.6750 MHZ
POLARIZATION (POL):  V
TRANSMITTER POWER (PWR):   50.0 DBM.            100.0 W
TRANSMITTING ANTENNA HEIGHT (HG1):     20.0 M.       66. FT
TRANSMITTING ANTENNA GAIN (G1):   15.0 DBI
RECEIVING ANTENNA HEIGHT (HG2):      1.8 M.       6. FT
RECEIVING ANTENNA GAIN (G2):   0.0 DBI
CLIMATE (CLIM):  CNTEMP
GROUND DESCRIPTOR (GND):  POOR       DIELECTRIC CONSTANT (EPS):    4.0   CONDUCTIVITY (SGM):    .0010
SURFACE REFRACTIVITY (NS):  301.0
                                        QT      QL      Q
VARIABILITIES, FIRST RUN (V1):        .300    .900    .900
VARIABILITIES, SECOND RUN (V2):       .900    .900    .500
VARIABILITIES, THIRD RUN (V3):        .900    .500    .500
OUTPUT DATA FORM:  MAP,  PLOT,  TABL=  8
                         LB,  RSL,

AREA BOUNDS:  ( 31,27,00,N/ 31,34,00,N/110,26,30,W/110,17,30,W)   ( 31.45,N/ 31.57,N/110.44,W/110.29,W)
TRANSMITTER LOCATION (XMTRLOC):  HUACHUCA
TRANSMITTER COORDINATES (XMTRCOOR):  ( 31,31,51,N/110,24,10,W)   ( 31.53,N/110.40,W)
```

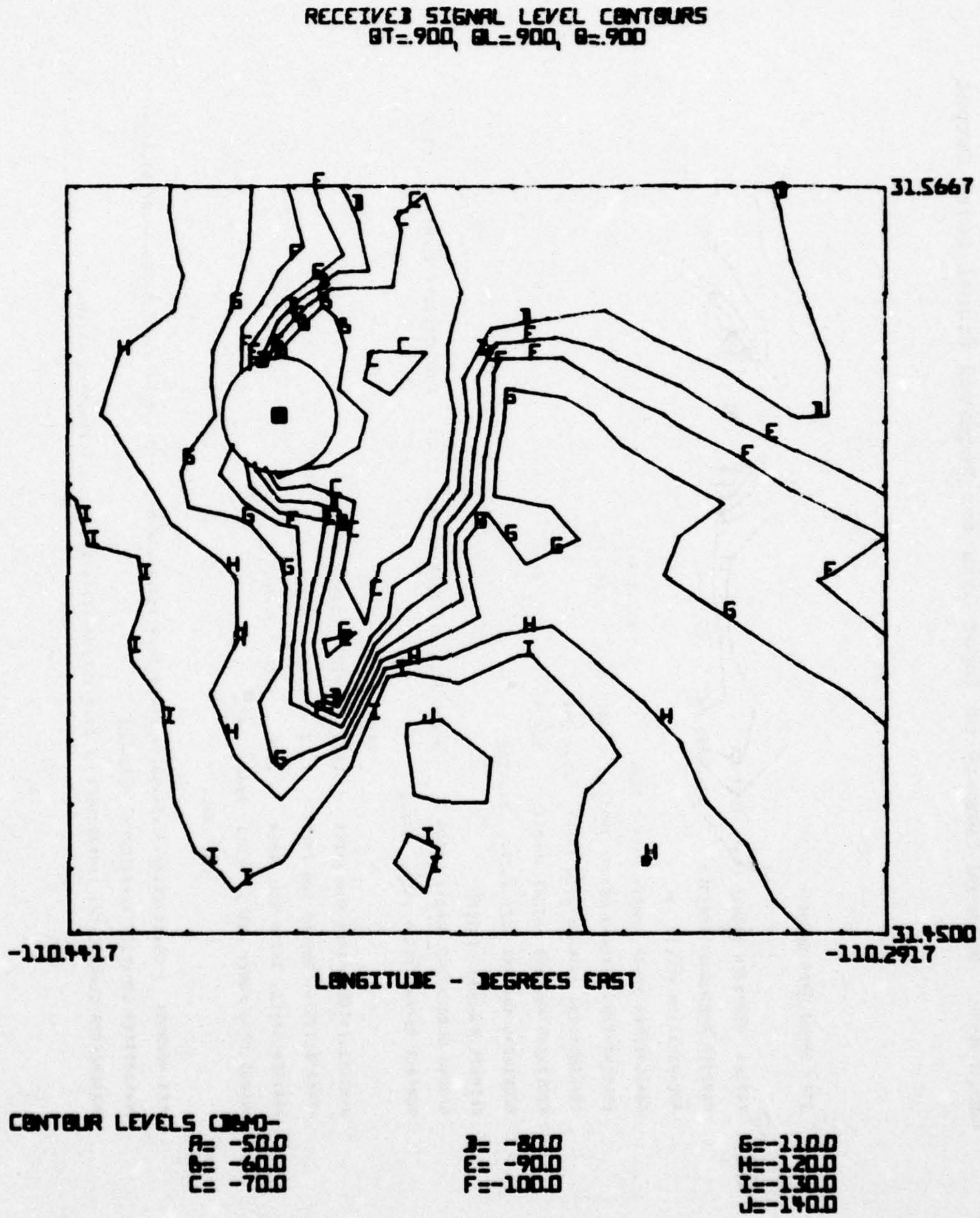

Figure A-2. Received signal level contours for V1 = (.90, .90, .90). Typical application of the CSPM in the geographical area mode.

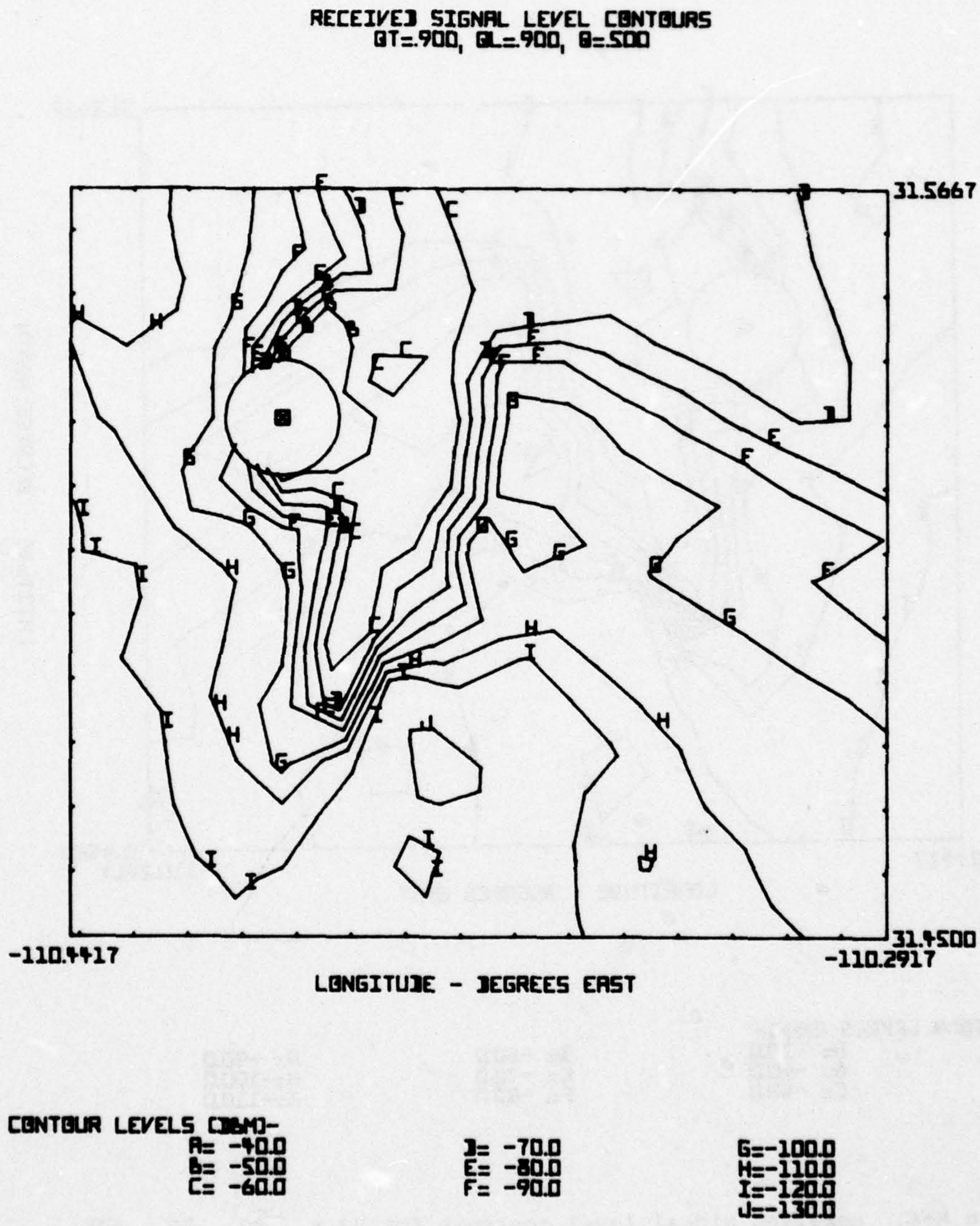

Figure A-3. Received signal level contours for V2 = (.90, .90, .50). Typical application of the CSPM in the geographical area mode.

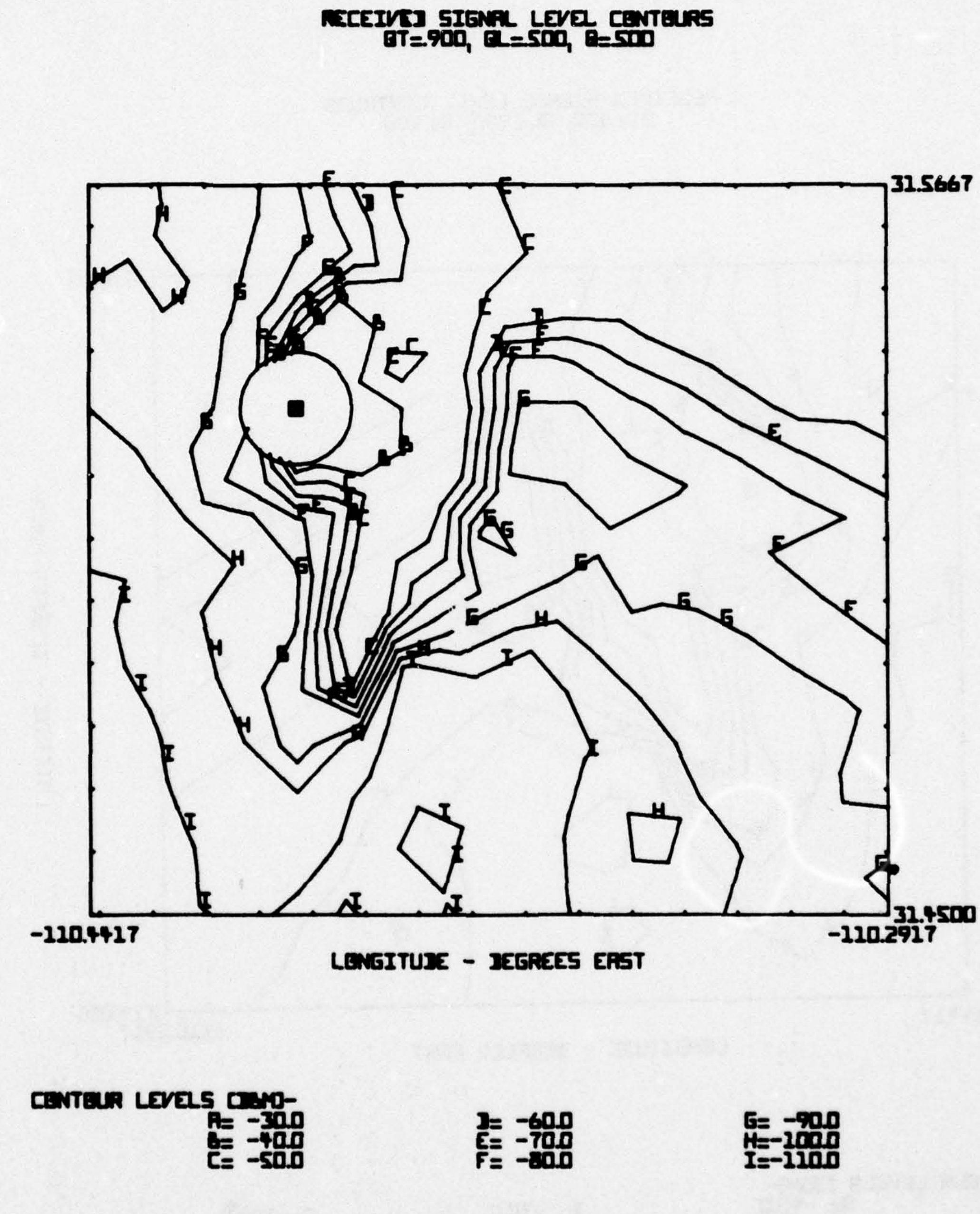

Figure A-4. Received signal level contours for V3 = (.90, .50, .50). Typical application of the CSPM in the geographical area mode.

Table A-6. Tabulated Received Signal Levels for Radial at 0°

CSPM EVALUATION DATA FOR RADIAL BEARING 0.00 DEGREES CW FROM NORTH.
PATH LENGTH: 3.99 KM. 2.48 MI
TERRAIN IRREGULARITY (DLTH): 297.7 M. 977. FT SURFACE REFRACTIVITY (NS): 301.0N-UNITS

DISTANCE			BASIC TRANSMISSION LOSS (LB) UNITS: DB				RECEIVED SIGNAL LEVEL (RSL) UNITS: DBM		
			V1	V2	V3		V1	V2	V3
		(QT)	.900	.900	.900	(QT)	.900	.900	.900
		(QL)	.900	.900	.500	(QL)	.900	.900	.500
KM	MI	(Q)	.900	.500	.500	(Q)	.900	.500	.500
1.00	.62		121.30	110.70	99.19		-56.30	-45.70	-34.19
2.00	1.24		159.91	149.36	136.70		-93.91	-83.36	-71.70
3.00	1.86		170.87	160.36	148.59		-105.87	-95.36	-83.59
4.00	2.49		168.29	157.86	145.96		-103.29	-92.86	-80.96

Table A-7 Tabulated Received Signal Levels for Radial at 45°

CSPM EVALUATION DATA FOR RADIAL BEARING 45.00 DEGREES CW FROM NORTH.
PATH LENGTH: 5.64 KM. 3.51 MI
TERRAIN IRREGULARITY (DLTH): 371.6 M. 1219. FT SURFACE REFRACTIVITY (NS): 301.0N-UNITS

DISTANCE			BASIC TRANSMISSION LOSS (LB) UNITS: DB				RECEIVED SIGNAL LEVEL (RSL) UNITS: DBM		
			V1	V2	V3		V1	V2	V3
		(QT)	.900	.900	.900	(QT)	.900	.900	.900
		(QL)	.900	.900	.500	(QL)	.900	.900	.500
KM	MI	(Q)	.900	.500	.500	(Q)	.900	.500	.500
1.00	.62		120.50	109.87	99.12		-55.50	-44.87	-33.12
2.00	1.24		127.49	116.90	105.02		-62.49	-51.90	-40.02
3.00	1.86		131.70	121.13	109.15		-66.70	-56.13	-44.15
4.00	2.49		134.75	124.21	112.14		-69.75	-59.21	-47.14
5.00	3.11		137.16	126.64	114.49		-72.16	-61.64	-49.49
6.00	3.73		139.18	128.69	116.48		-74.18	-63.69	-51.48

Table A-8. Tabulated Received Signal Levels for Radial at 90°

CSPM EVALUATION DATA FOR RADIAL BEARING 90.00 DEGREES CW FROM NORTH.
PATH LENGTH: 10.54 KM, 6.55 MI
TERRAIN IRREGULARITY (DLTH): 451.6 M, 1482. FT SURFACE REFRACTIVITY (NS): 301.0N-UNITS

DISTANCE		BASIC TRANSMISSION LOSS (LB) UNITS: DB			RECEIVED SIGNAL LEVEL (RSL) UNITS: DBM		
		V1	V2	V3	V1	V2	V3
	(QT)	.900	.900	.900	.900	.900	.900
	(QL)	.900	.900	.500	.900	.900	.500
KM	MI (Q)	.900	.500	.500	.900	.500	.500
1.00	.62	121.39	110.76	98.83	-56.39	-45.76	-33.83
2.00	1.24	128.38	117.77	105.74	-63.39	-52.77	-40.74
3.00	1.86	132.72	122.15	110.02	-67.72	-57.15	-45.02
4.00	2.49	178.56	168.03	155.83	-113.56	-103.03	-90.83
5.00	3.11	178.95	168.45	156.20	-113.95	-103.45	-91.20
6.00	3.73	170.39	159.93	147.62	-105.39	-94.93	-82.62
7.00	4.35	162.55	152.13	139.75	-97.55	-87.13	-74.78
8.00	4.97	152.23	141.85	129.45	-87.23	-76.85	-64.45
9.00	5.59	144.39	133.97	121.55	-79.39	-68.97	-56.55
10.00	6.21	145.52	135.14	122.68	-80.52	-70.14	-57.68
11.00	6.84	146.56	136.19	123.71	-81.56	-71.19	-58.71

Table A-9. Tabulated Received Signal Levels for Radial at 135°

CSPM EVALUATION DATA FOR RADIAL BEARING 135.00 DEGREES CW FROM NORTH.
PATH LENGTH: 12.72 KM, 7.90 MI
TERRAIN IRREGULARITY (DLTH): 760.8 M, 2496. FT SURFACE REFRACTIVITY (NS): 301.0N-UNITS

DISTANCE		BASIC TRANSMISSION LOSS (LB) UNITS: DB			RECEIVED SIGNAL LEVEL (RSL) UNITS: DBM		
		V1	V2	V3	V1	V2	V3
	(QT)	.900	.900	.900	.900	.900	.900
	(QL)	.900	.900	.500	.900	.900	.500
KM	MI (Q)	.900	.500	.500	.900	.500	.500
1.00	.62	123.40	112.74	100.47	-58.40	-47.74	-35.47
2.00	1.24	130.31	119.69	107.35	-65.31	-54.69	-42.35
3.00	1.86	130.75	120.13	107.73	-65.75	-55.13	-42.73
4.00	2.49	153.63	143.10	130.66	-88.63	-78.10	-65.66
5.00	3.11	175.23	164.77	152.29	-110.23	-99.77	-87.29
6.00	3.73	197.24	186.83	174.32	-132.24	-121.83	-109.32
7.00	4.35	196.32	186.46	173.92	-131.82	-121.46	-108.92
8.00	4.97	196.10	185.79	173.23	-131.10	-120.79	-108.23
9.00	5.59	192.50	182.24	169.65	-127.50	-117.24	-104.65
10.00	6.21	189.37	179.16	166.56	-124.37	-114.16	-101.56
11.00	6.84	188.13	177.96	165.34	-123.13	-112.96	-100.34
12.00	7.46	186.51	176.27	163.64	-121.51	-111.27	-98.64
13.00	8.08	185.39	175.21	162.57	-120.39	-110.21	-97.57

Table A-10. Tabulated Received Signal Levels for Radial at 180°

CSPM EVALUATION DATA FOR RADIAL BEARING 180.00 DEGREES CW FROM NORTH.
PATH LENGTH: 9.00 KM. 5.59 MI
TERRAIN IRREGULARITY (DLTH): 749.4 M. 2459. FT SURFACE REFRACTIVITY (NS): 301..N-UNITS

DISTANCE		BASIC TRANSMISSION LOSS (LB) UNITS: DB				RECEIVED SIGNAL LEVEL (RSL) UNITS: DBM		
			V1	V2	V3	V1	V2	V3
		(QT)	.900	.900	.900	(QT) .900	.900	.900
		(QL)	.900	.900	.500	(QL) .900	.900	.500
KM	MI	(Q)	.900	.500	.500	(Q) .900	.500	.500
1.00	.62		121.43	110.77	98.50	-56.43	-45.77	-33.30
2.00	1.24		170.50	159.92	147.59	-105.50	-94.92	-82.39
3.00	1.86		179.58	169.07	156.68	-114.58	-104.07	-91.68
4.00	2.49		176.02	165.50	153.07	-111.02	-100.50	-88.07
5.00	3.11		170.68	160.50	148.02	-105.68	-95.50	-83.02
6.00	3.73		172.85	162.37	149.87	-107.85	-97.37	-84.87
7.00	4.35		191.46	181.20	168.66	-126.46	-116.20	-103.66
8.00	4.97		196.09	185.89	173.33	-131.09	-120.89	-108.33
9.00	5.59		198.94	188.80	176.22	-133.94	-123.80	-111.22

Table A-11. Tabulated Received Signal Levels for Radial at 225°

CSPM EVALUATION DATA FOR RADIAL BEARING 225.00 DEGREES CW FROM NORTH.
PATH LENGTH: 5.22 KM. 3.24 MI
TERRAIN IRREGULARITY (DLTH): 632.7 M. 2076. FT SURFACE REFRACTIVITY (NS): 301.0N-UNITS

DISTANCE		BASIC TRANSMISSION LOSS (LB) UNITS: DB				RECEIVED SIGNAL LEVEL (RSL) UNITS: DBM		
			V1	V2	V3	V1	V2	V3
		(QT)	.900	.900	.900	(QT) .900	.900	.900
		(QL)	.900	.900	.500	(QL) .900	.900	.500
KM	MI	(Q)	.900	.500	.500	(Q) .900	.500	.500
1.00	.62		161.24	150.61	138.44	-96.24	-85.61	-73.44
2.00	1.24		169.69	159.12	146.87	-104.69	-94.12	-81.87
3.00	1.86		193.08	182.58	170.26	-128.08	-117.58	-105.26
4.00	2.49		197.06	186.62	174.25	-132.06	-121.62	-109.25
5.00	3.11		199.46	189.08	176.67	-134.46	-124.08	-111.67
6.00	3.73		200.91	190.59	178.14	-135.91	-125.59	-113.14

Table A-12. Tabulated Received Signal Levels for Radial at 270°

CSPM EVALUATION DATA FOR RADIAL BEARING 270.00 DEGREES CW FROM NORTH.
PATH LENGTH: 3.69 KM, 2.29 MI
TERRAIN IRREGULARITY (DLTH): 497.0 M, 1630. FT SURFACE REFRACTIVITY (NS): 301.0N-UNITS

DISTANCE			BASIC TRANSMISSION LOSS (LB) UNITS: DB				RECEIVED SIGNAL LEVEL (RSL) UNITS: DBM		
			V1	V2	V3		V1	V2	V3
		(QT)	.900	.900	.900	(QT)	.900	.900	.900
		(QL)	.900	.900	.500	(QL)	.900	.900	.500
KM	MI	(Q)	.900	.500	.500	(Q)	.900	.500	.500
1.00	.62		174.21	163.59	151.58		-109.21	-98.59	-86.58
2.00	1.24		181.29	170.72	159.62		-116.29	-105.72	-93.62
3.00	1.86		184.42	173.88	161.70		-119.42	-108.88	-96.70
4.00	2.49		189.13	178.70	166.45		-124.13	-113.70	-101.45

Table A-13. Tabulated Received Signal Levels for Radial at 315°

CSPM EVALUATION DATA FOR RADIAL BEARING 315.00 DEGREES CW FROM NORTH.
PATH LENGTH: 5.22 KM, 3.24 MI
TERRAIN IRREGULARITY (DLTH): 499.2 M, 1638. FT SURFACE REFRACTIVITY (NS): 301.0N-UNITS

DISTANCE			BASIC TRANSMISSION LOSS (LB) UNITS: DB				RECEIVED SIGNAL LEVEL (RSL) UNITS: DBM		
			V1	V2	V3		V1	V2	V3
		(QT)	.900	.900	.900	(QT)	.900	.900	.900
		(QL)	.900	.900	.500	(QL)	.900	.900	.500
KM	MI	(Q)	.900	.500	.500	(Q)	.900	.500	.500
1.00	.62		168.42	157.79	145.79		-103.42	-92.79	-80.79
2.00	1.24		179.16	168.60	156.49		-114.16	-103.60	-91.49
3.00	1.86		189.51	179.01	166.82		-124.51	-114.01	-101.82
4.00	2.49		188.18	177.74	165.49		-123.18	-112.74	-100.49
5.00	3.11		190.93	180.56	168.25		-125.93	-115.56	-103.25
6.00	3.73		193.36	183.05	170.70		-128.36	-118.05	-105.70

Table A-14. Printed Summary of Input Data for Communication Reliability

```
CSPM INPUT DATA SUMMARY


TITLE:  COMMUNICATION RELIABILITY TEST

CARRIER FREQUENCY (FREQ):       245.798 MHZ

POLARIZATION (POL):  H

TRANSMITTER POWER (PWR):   50.0 DBM,              100.0 W

TRANSMITTING ANTENNA HEIGHT (HG1):      10.0 M,        33. FT

TRANSMITTING ANTENNA GAIN (G1):   10.0 DBI

RECEIVING ANTENNA HEIGHT (HG2):       1.8 M,         6. FT

RECEIVING ANTENNA GAIN (G2):   0.0 DBI

CLIMATE (CLIM):  CNTEMP

GROUND DESCRIPTOR (GND):  POOR        DIELECTRIC CONSTANT (EPS):    4.0   CONDUCTIVITY (SGM):    .0010

SURFACE REFRACTIVITY (NS):  301.0

RECEIVED SIGNAL LEVEL THRESHOLD (RSLTH):   -93.5 DBM

                                          QT       QL       Q

VARIABILITIES, FIRST RUN (V1):      .950     .950     .500

VARIABILITIES, SECOND RUN (V2):     .950     .500     .500

VARIABILITIES, THIRD RUN (V3):      .500     .500     .500

COMMUNICATION RELIABILITY CONTOUR LEVELS (RQ):  .990    .900    .500    .100

OUTPUT DATA FORM:  MAP,  PLOT

                          LB,  REL,


AREA BOUNDS:  ( 31,27,00,N/ 31,34,00,N/110,26,30,W/110,17,30,W)    ( 31.45,N/ 31.57,N/110.44,W/110.29,W)

TRANSMITTER LOCATION (XMTRLOC):  HUACHUCA

TRANSMITTER COORDINATES (XMTRCOOR):  ( 31,31,51,N/110,24,10,W)    ( 31.53,N/110.40,W)
```

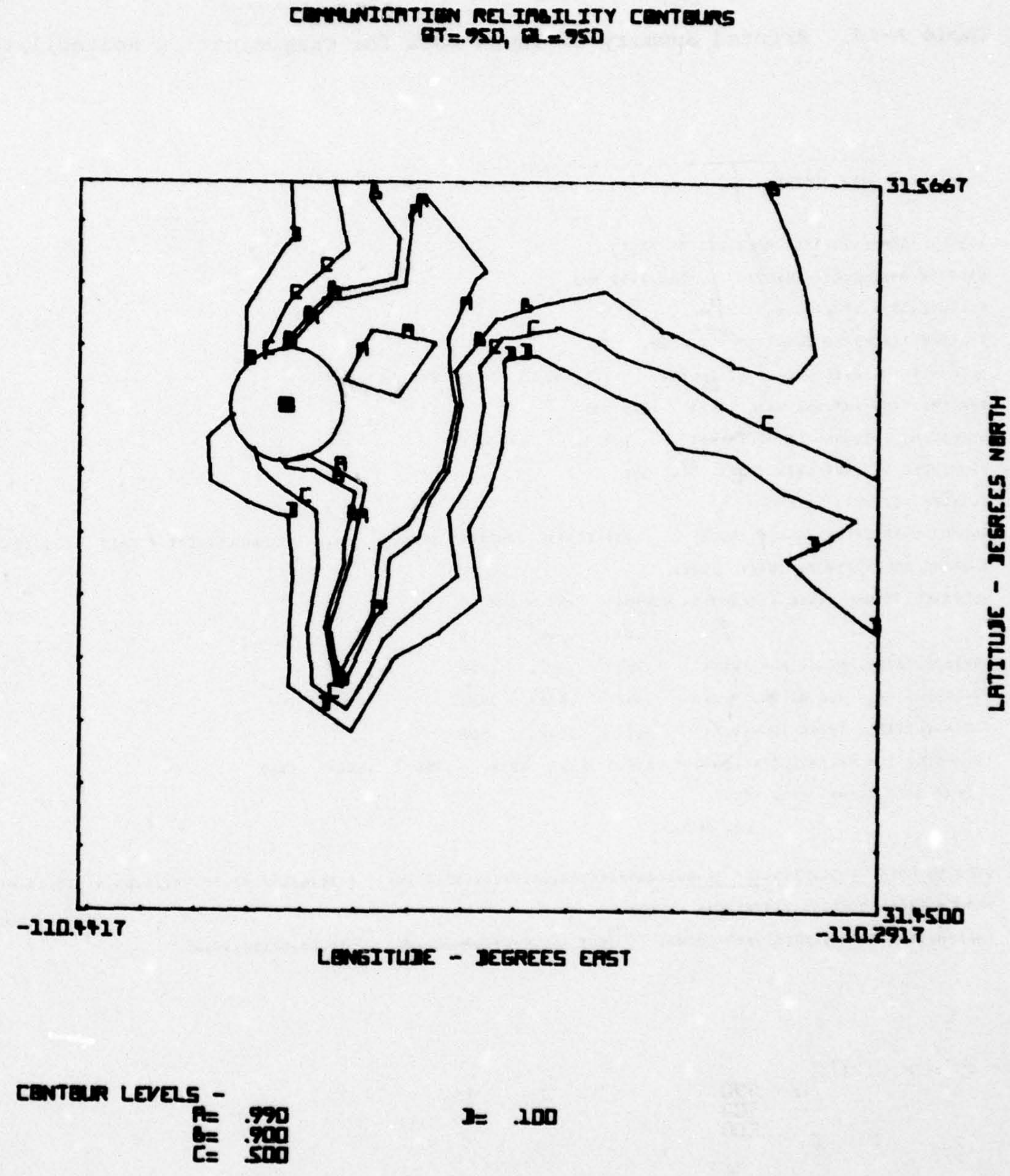

Figure A-5. Communication reliability contours for V1 = (.95, .95). Typical application of the CSPM in the geographical area mode.

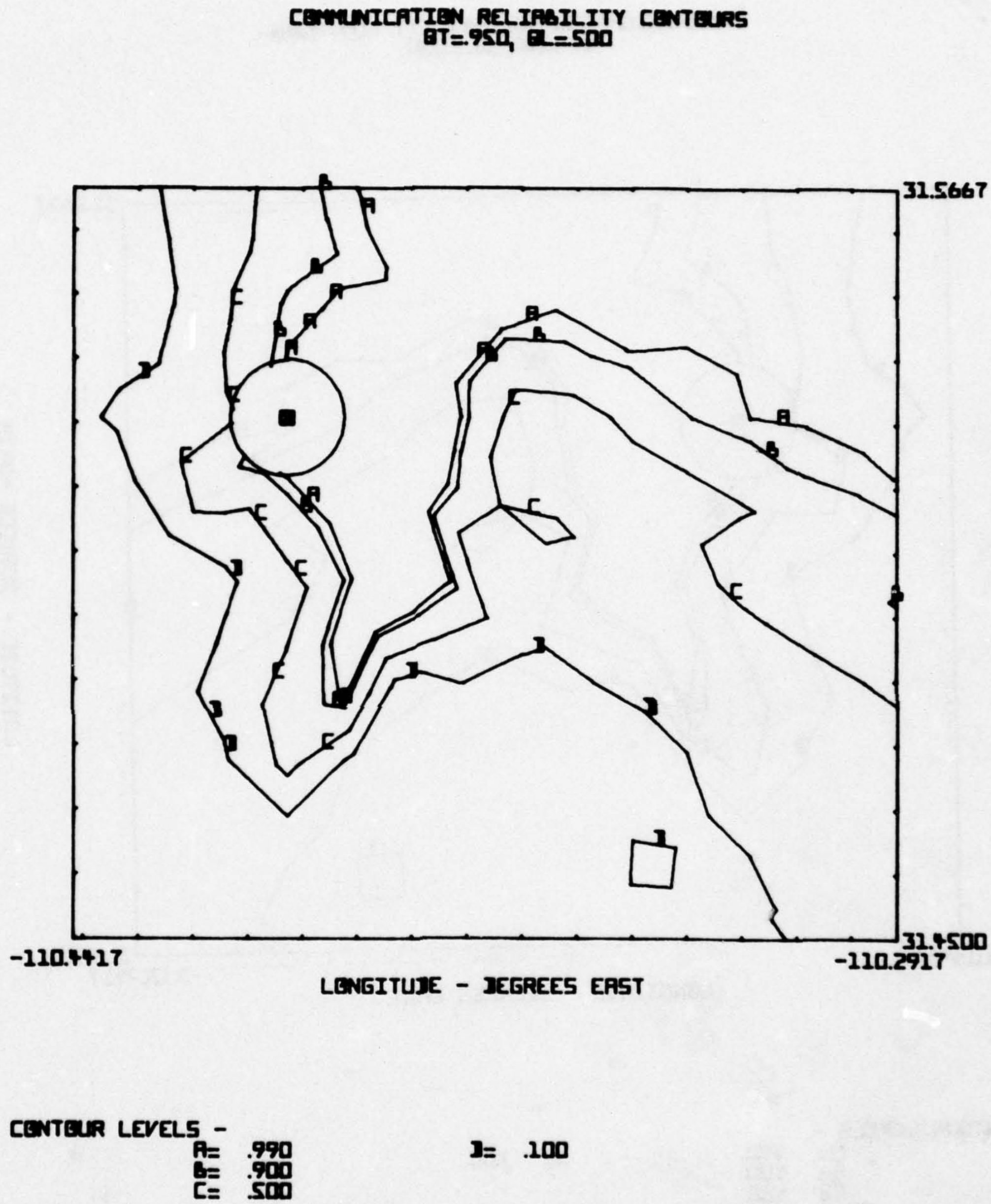

Figure A-6. Communication reliability contours for V2 = (.95, .50). Typical application of the CSPM in the geographical area mode.

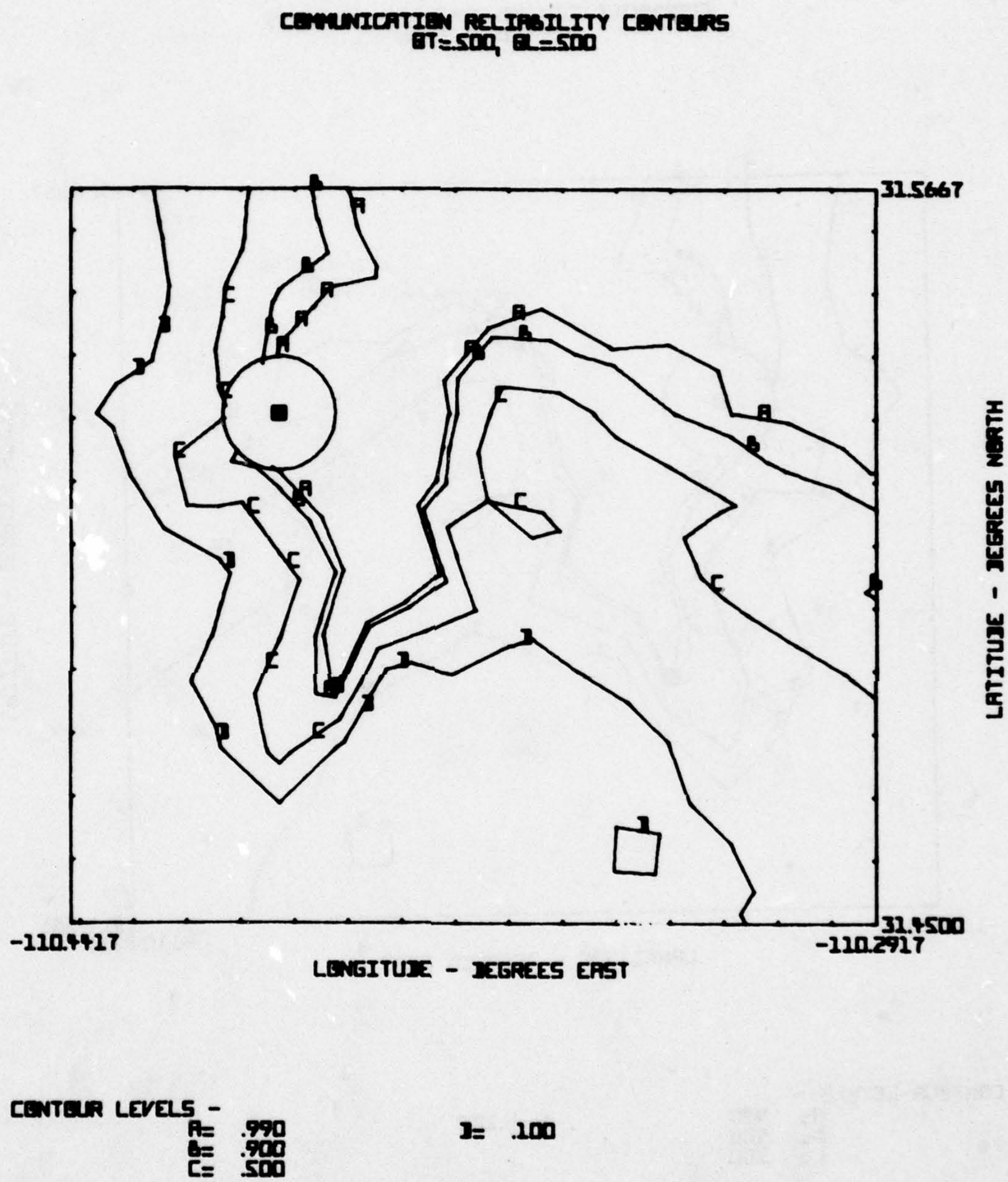

Figure A-7. Communication reliability contours for V3 = (.50, .50). Typical application of the CSPM in the goegraphical area mode.

are used are POL = H, G1 = 10, and G2 = 0. A printed summary of the input used to produce the communication reliability output is shown in Table A-4. Figures A-5, A-6, and A-7 are the plotted output of communication reliability.

A.4 REFERENCES

Bean, B.R., J.D. Horn, and A.M. Ozanich, Jr. (1960, Climatic charts and data of the radio refractive index for the United States and the world, NBS Monograph No. 22.

CCIR (1974)*, Radiometeorological data, Report 563, Vol. V, XIIIth Plenary Assembly, Geneva.

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*Published by the Internation Telecommunication Union, Geneva, Switzerland.

APPENDIX B. COMMUNICATION SYSTEM PERFORMANCE MODEL SOFTWARE TECHNICAL DESCRIPTION

Technical description of the Communication System Performance Model (CSPM) software given in this section is intended to serve as a guide for program maintenance and modification. The first section includes a general overview of program structure, processing flow, file and record descriptions, and common block definitions. Documentation for each individual routine is given in the second section. The third section describes how to install the CSPM on a CDC 6500 computer system.

B.1 General Overview

The CSPM has been developed for the Army's CEEIA as an aid in designing and evaluating Army communication systems. The Longley-Rice propagation prediction loss model is used in the point-to-point mode to determine basic transmission loss statistics which are used to calculate power density, received signal level, and communication reliability. These values may be tabulated for selected paths within a geographic area or used to produce contour plots over the area. Tabulated or plotted path profiles also may be requested for selected paths within the area. If a single (discrete) path, rather than a geographic area, is to be analyzed, the CSPM will produce a tabulated or plotted profile and calculate the basic trnasmission loss for the path. A restart option is available to allow the user to input new statistical values and output options to be used with the data from a LOSS file created in a previous run. The CSPM then calculates, tabulates, and plots another set of values for basic transmission loss, power density, received signal level, and communication reliability for the same geographic area.

The process diagram for the CSPM (Figure B-1) shows the organization and flow of the four major parts of the program. The model is divided into a primary overlay and three secondary overlays to minimize the core required for execution. The primary overlay (CSPM) defines the files and common blocks used throughout the program. It controls execution by calling the secondary overlays as they are needed. The (1,0) overlay (INPUT) reads

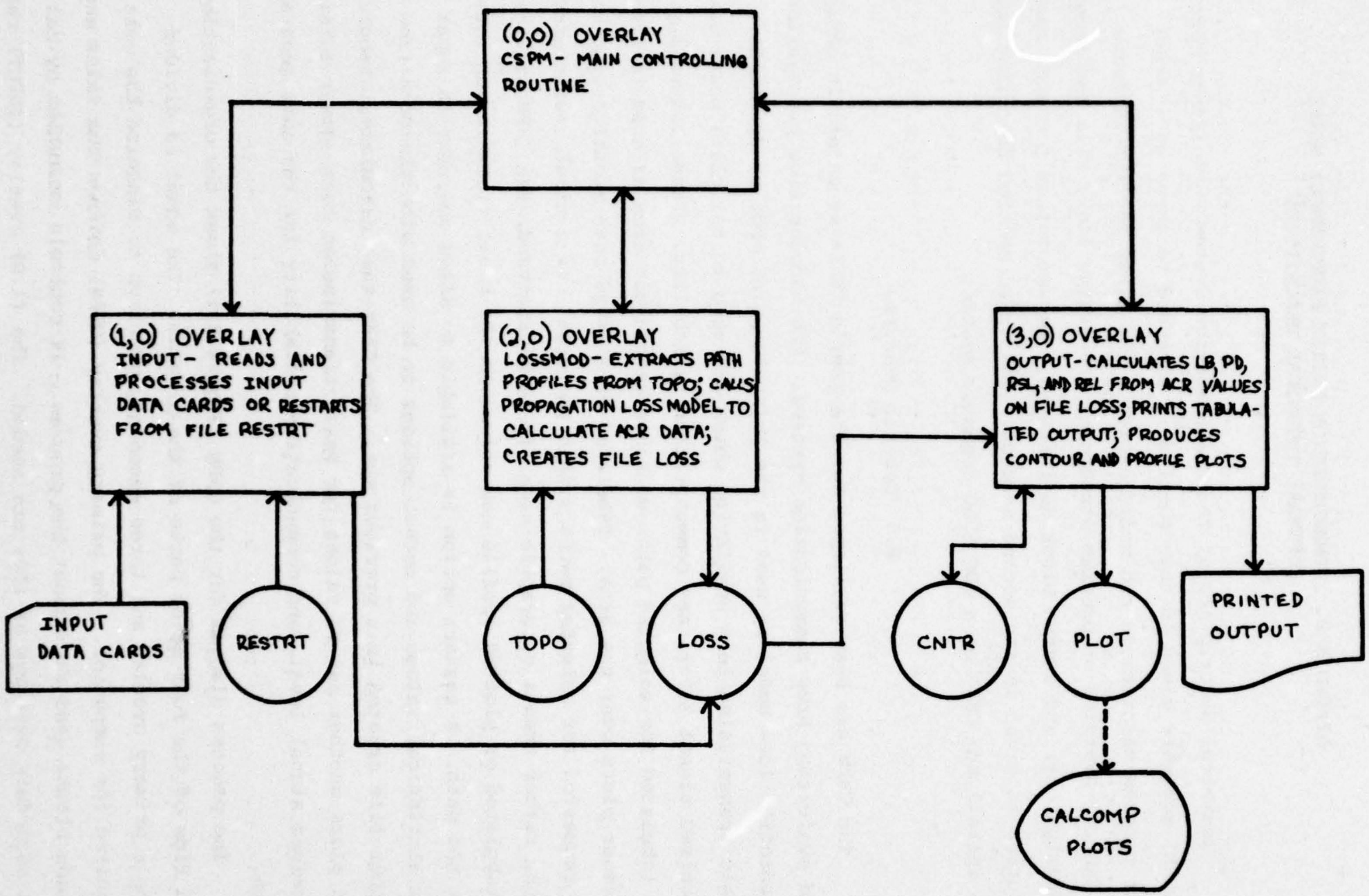

Figure B-1. CSPM program organization.

the free-format input data cards, checks for a restart file, determines if any errors or conflicts exist in the input options, stores the input values in the /OPTIONS/ common block, and prints the input data summary. The (2,0) overlay (LOSSMOD) extracts path profiles from the topographic data base and uses the Longley-Rice propagation model to calculate ACR values (attenuations relative to free-space losses) and statistical values for data points on that path. The (3,0) overlay (OUTPUT) reads the profile and ACR data from file LOSS or RESTRT, if it is a restart run, and prints tabulated values or produces CALCOMP plots of the path profile or contour plots over the geographic area.

Figure B-2 gives a more detailed description of the primary overlay (CSPM) execution flow. Program CSPM initially issues the starting dayfile messages and calls a system routine to return the starting CP time which is used later with the final CP time to calculate the execution time for the run. Next, CSPM calls the INPUT overlay to read the user input data cards and check for a restart file. If any fatal errors are detected during input processing, CSPM displays the number of errors in a dayfile message and aborts the run. If no errors are found, CSPM checks the restart flag to determine if the LOSSMOD is called to extract path profiles and generate ACR and statistical data for a single path or over a geographic area. If fatal errors are encountered during the profile extraction due to missing data on the TOPO data base, CSPM will abort the run. When all the data have been calculated and written to file LOSS, CSPM calls the OUTPUT overlay to read the LOSS file and produce the requested tabulated and plotted output. If this is a restart run, OUTPUT reads the data from file RESTRT, since no new LOSS file has been generated. When all the requested output has been produced, CSPM issues the final dayfile messages to signify that the run completed normally. When CSPM has finished executing, it is the user's responsibility to dispose the PLOT file to the CALCOMP plotter and (save the LOSS file for use in future restart runs). Table B-1 lists the files that are defined by CSPM and gives a brief description of the type of data contained in each. The record structures for files LOSS and CNTR are described in Tables B-2 and B-3. CSPM also defines two common blocks that are used throughout the program. The variables in common block /OPTIONS/ are described

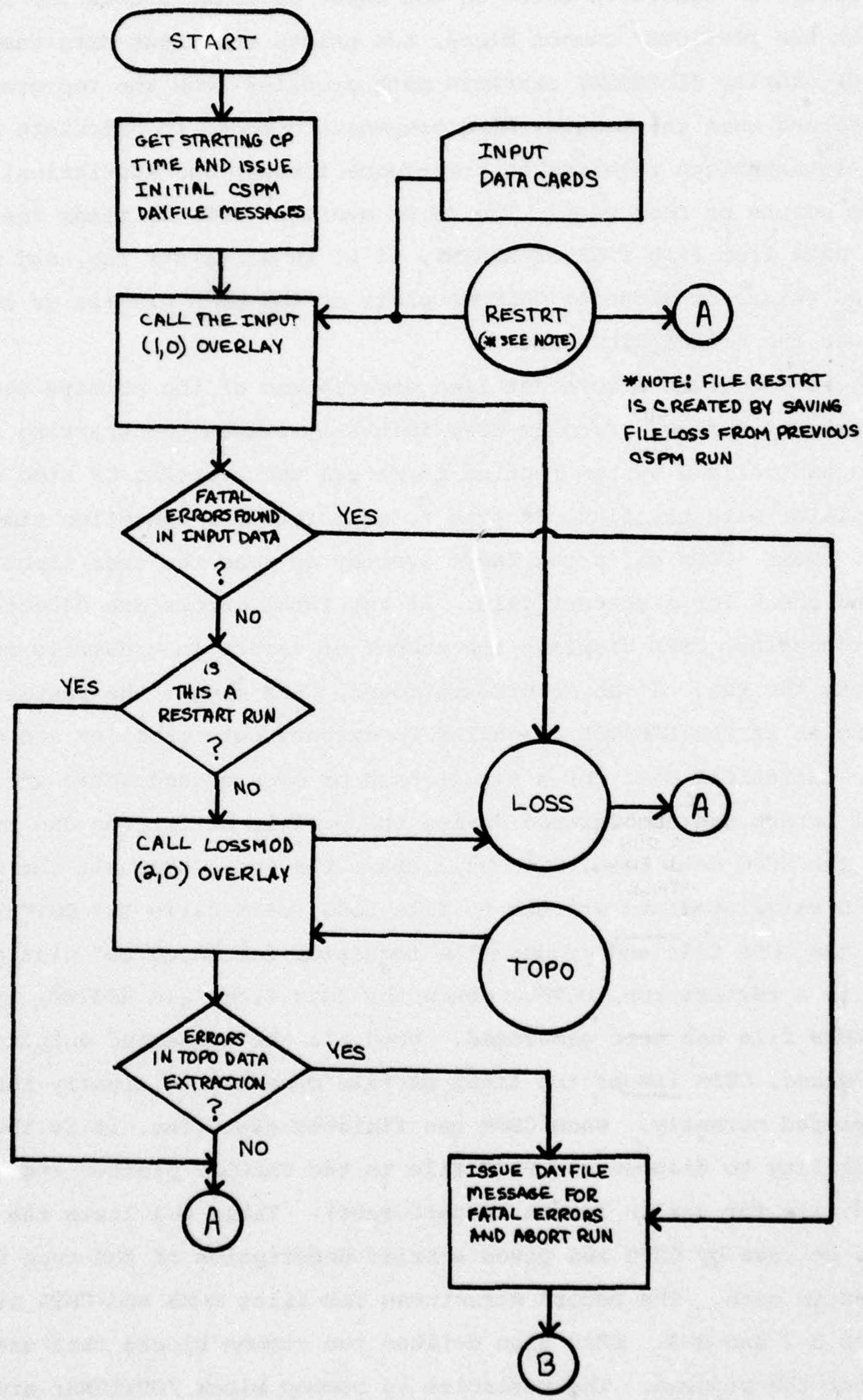

Figure B-2. Process diagram for overlay (0,0) - CSPM.

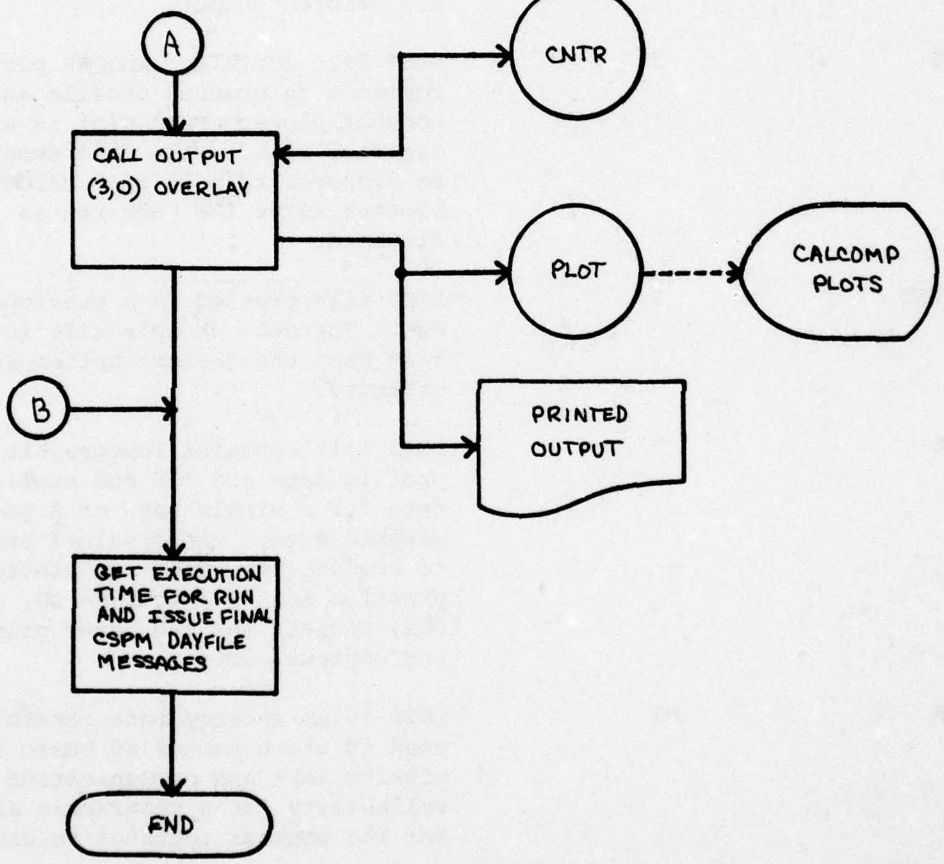

Figure B-2. Continued.

Table B-1. Files Used by CSPM

File Name	Logical Unit Number	Description
INPUT	5	INPUT file for the CSPM contains the user data cards.
OUTPUT	6	OUTPUT file for the CSPM is used for all printed output.
PLOT	7	PLOT file contains CALCOMP plotter commands to produce profile and contour plots. Each plot is a separate file. This file should be disposed to a 12 inch CALCOMP plotter after the CSPM run is finished.
RESTRT	8	LOSS file created in a previous run. The data on this file is read when the restart option is selected.
LOSS	9	LOSS file contains topographic path profile data and ACR and statistical data for a single path or a geographic area. These values are used to produce tabulated and plotted path profiles and to calculate LB, PD, RSL, and REL for tabulated printouts and contour plots.
CNTR	10	CNTR is an intermediate scratch file used to store values of basic transmission loss and communication reliability for a geographic area for the contour routines to use.

Table B-2. Record Structure for File LOSS

File LOSS contains three types of records:

OPTIONS - the values in common block /OPTIONS/ are written to file LOSS as the first record. If this file is used later with the restart option, all the options and data values used in the initial run are available.

PROFILE - contains topographic elevation data for the path profile along with the path parameter information.

ACR DATA - contains the eight ACR and statistical values needed to calculate basic transmission loss for each data point along the path. The bearing, path length, and number of data points on the path also are given.

For a single path, the LOSS file will contain only the OPTIONS record followed by a PROFILE record for the path and, optionally, an ACR DATA record if LB has been requested for the path. When a geographic area is being analyzed, the paths (map radials) are processed in clockwise order from north. If the radial being used has been selected for a tabulated or plotted path profile, the PROFILE record will be written to file LOSS. If tabulated data values (LB, PD, RSL, REL) have been requested for this radial or contour plots have been requested, an ACR DATA record will be written to file LOSS following the PROFILE record. Thus, for LOSS files created under the MAP option, the PROFILE and ACR DATA records are interspersed depending on the other options selected.

The structures of these records are shown below:

Record Type	Word Number	Description
PROFILE		Path profile records contain the topographic elevation data and path parameters necessary to produce tabulated and plotted path profiles.
	1(N)	Number of words to follow in the record.
	2 (FLAG)	Set to -1 to flag this record as a profile.
	3 (TYPE)	Set to -1 if this profile is to be plotted only, to 0 if it is to be tabulated only, and to 1 if both tabulated and plotted output are requested.

Table B-2. (Continued)

Record Type	Word Number	Description
	4 (AZIM)	Bearing of the path in decimal degrees, clockwise from north.
	5 (DLTH)	Terrain irregularity in meters for the path.
	6 (ENS)	Surface refractivity for the path.
	7 (HSE(1))	Effective surface elevation in meters at the transmitter.
	8 (HSE(2))	Effective surface elevation in meters at the receiver.
	9 (DL(1))	Distance in meters from the transmitter to its horizon.
	10 (DL(2))	Distance in meters from the receiver to its horizon.
	11 (HL(1))	Transmitter horizon elevation in meters.
	12 (HL(2))	Receiver horizon elevation in meters.
	13 (DIST)	Path length in meters.
	14 (XI)	Distance increment in meters between profile points.
	15 (NP)	Number of points on the profile including the point at the transmitter but not the point at the receiver.
	16 to N-15	NP+1 words containing elevations in meters for each profile point.
ACR DATA		ACR records contain the attenuation and statistical values necessary to calculate LB, PD, RSL, and REL for the data points on the path.
	1 (N)	Number of words to follow in the record.
	2 (FLAG)	Set to 1 if tabulated data values are to be printed for this path and to 0 if data are only to be used for contour plots.

Table B-2. (Continued)

Record Type	Word Number	Description
	3 (AZIM)	Bearing of the path in decimal degrees, clockwise from north.
	4 (STDIST)	Distance in kilometers from the transmitter to the first data point on the path.
	5 (PATHDST)	Path length in meters.
	6 (DLTH)	Terrain irregularity in meters for the path.
	7 (ENS)	Surface refractivity for the path.
	8 (NUM)	Number of data points on this path for which a set of ACR values follow.
	A set of eight values follows for each data point on the path (repeat for K=1,NUM)	
	(K-1)*8+9 (XLBF)	Free space loss in dB for the path.
	(K-1)*8+10 (ACRV)	A predicted reference value of attenuation below free space in dB.
	(K-1)*8+11 (VMD)	The deviation of calculated reference attenuation from yearly median attenuation - a function of climatic region and effective distance.
	(K-1)*8+12 (SGC)	Standard deviation of prediction error.
	(K-1)*8+13	Standard deviation of predicted attenuation due to location variability.
	(K-1*8+14 (SGTM)	Standard deviation of predicted attenuation for time variabilities less than the median value.
	(K-1)*8+15 (SGTP)	Standard deviation of predicted attenuation for time variabilities greater than the median value.

Table B-2. (Continued)

Record Type	Word Number	Description
	(K-1)*8+16 (SGTD)	Standard deviation of predicted attenuation for small time variabilities, such as are associated with the ducting phenomenon.

Table B-3. Record Structure for File CNTR

Program OUTPUT writes a record in the following format to file CNTR for each path (map radial) in the geographic area being analyzed. The routine CONTOUR reads these data and uses them to generate the requested contour plots.

Word Number	Description
1 (STDIST)	Distance in kilometers from the transmitter to the first data point on the path.
2 (AZIM)	Bearing of the radial in decimal degrees clockwise from north.
3 (NP)	Number of data points on the path.
4 to NP+3 (XLOSS(V1,J),J=1,NP)	Basic transmission loss values for all data points for variability set V1.
NP+4 to 2*NP+3 (XLOSS(V2,J),J=1,NP)	Basic transmission loss values for all data points for variability set V2.
2*NP+4 to 3*NP+3 (XLOSS(V3,J),J=1,NP)	Basic transmission loss values for all data points for variability set V3.
3*NP+4 to 4*NP+3 (XREL(V1,J),J=1,NP)	Communication reliability values for all data points for variability set V1.
4*NP+4 to 5*NP+3 (XREL(V2,J),J=1,NP)	Communication reliability values for all data points for variability set V2.
5*NP+4 to 6*NP+3 (XREL(v3,J),J=1,NP)	Communication reliability values for all data points for variability set V3.

Table B-4. Variables in Common Block /OPTIONS/

Variable Name	Description
TITLE	Title for the CSPM run (60 characters maximum).
IDATE	Date of the CSPM run.
ITIME	Time of the CSPM run.
MAP	Flag set to 0 for single path and to 1 for map option.
BLAT1, BLAT2, BLON1, BLON2	The latitude and longitude boundaries in decimal degrees of the map area.
PRO	Number of path profiles to be plotted.
PTAB	Number of path profiles to be tabulated.
PLOT	Flag set to 1 if contour plots are requested and to 0 if no plots are to be produced.
TABL	Number of paths for which LB, PD, RSL, and REL will be tabulated.
LB	Flag set to 1 if basic transmission losses are to be tabulated or plotted and to 0 otherwise.
PD	Flag set to 1 if power density values are to be tabulated or plotted and to 0 otherwise.
RSL	Flag set to 1 if received signal level values are to be tabulated or plotted and to 0 otherwise.
REL	Flag set to 1 if communication reliability values are to be tabulated or plotted and to 0 otherwise.
XLAT	Transmitter latitude in decimal degrees north.
XLON	Transmitter longitude in decimal degrees east.
RLAT	Receiver latitude in decimal degrees north.
RLON	Receiver longitude in decimal degrees east.
XLOC	Name of transmitter location.

Table B-4. (Continued)

Variable Name	Description
RLOC	Name of receiver location.
POL	Polarization of transmitting antenna.
CLIM	Climate descriptor.
GND	Ground descriptor.
FREQ	Carrier frequency in MHz.
PWR	Transmitter power in dBm.
HG1	Transmitter antenna height in meters.
HG2	Receiver antenna height in meters.
G1	Transmitter antenna gain in dBi.
G2	Receiver antenna gain in dBi.
EPS	Ground dielectric constant.
SGM	Ground conductivity.
ENS	If negative, ABS(ENS = NS (surface refractivity), and if positive, ENS = NO (surface refractivity referenced to mean sea level).
RSLTH	Received signal level threshold in dBm.
PWRW	Transmitter power in watts.
HG1F	Transmitter antenna height in feet.
HG2F	Receiver antenna height in feet.
V1, V2, V3	Three sets of variability statistics (Particular QT, QL, Q values from one set of variability statistics.)
NV	Number of sets of variability statistics to be used in the CSPM run.
RQ	Contour levels specified for REL plots.

Table B-4. (Continued)

Variable Name	Description
NRQ	Number of contour levels to be used for REL plots.
RESTART	Flag set to 1 if the restart option has been selected and to 0 if not.
NERR	Number of fatal errors found.
XCDMS	Transmitter coordinates in degrees, minutes, seconds display code format (XXX,XX,XX,D/XXX,XX,XX,D).
XCDD	Transmitter coordinates in decimal degrees display code format (XXX.XX,D/XXX.XX,D).
RCDMS	Receiver coordinates in degrees, minutes, seconds display code format (XXX,XX,XX,D/XXX,XX,XX,D).
RCDD	Receiver coordinates in decimal degrees display code format (XXX.XX,D/XXX.XX,D).
MCDMS	Map bounds coordinates in degrees minutes, seconds display code format (XXX,XX,XX,D/XXX,XX,XX,D/XXX,XX,XX,D/XXX,XX,XX,D).
MCDD	Map bounds coordinates in decimal degrees display code format (XXX.XX,D/XXX.XX,D/XXX.XX,D/XXX.XX,D).

Table B-5. Variables in Common Block /LOSSMOD/

Variable Name	Description
XMAX	Distance in meters from the transmitter to the east longitude boundary of the map area.
XMIN	Distance in meters from the transmitter to the west longitude boundary of the map area.
YMAX	Distance in meters from the transmitter to the north latitude boundary of the map area.
YMIN	Distance in meters from the transmitter to the north latitude boundary of the map area.
B1	Bearing in decimal degrees to the NE corner of the map area.
B2	Bearing in decimal degrees to the SE corner of the map area.
B3	Bearing in decimal degrees to the SW corner of the map area.
B4	Bearing in decimal degrees to the NW corner of the map area.
ZZD	Standard normal deviate for time variability in attenuation at small probabilities (often associated with the phenomonen of ducting).

in Table B-4 and those in /LOSSMOD/ in Table B-5. These data values and option flags are referenced in many routines in each overlay.

The execution flow of the (1,0) overlay is shown in Figure B-3. INPUT, first, initializes necessary flags and data values and then reads the title card for the run. It then checks for a RESTRT file by attempting to read the OPTIONS record from it. If the read is successful, the /OPTIONS/ common block will be reset to the values used when the RESTRT file was created. Input then sets the restart flag and identifies the options that may not be respecified for a restart run as illegal. If an EOF is read, INPUT sets its flags for an initial run. In either case, INPUT then proceeds to read the options from the user input data cards. The NXTVAR routine is called to read the data cards as needed and return the next syntactic elements and numeric values. It is described in Table B-6. As each new option keyword is read, INPUT checks it against a list of legal keywords. It also checks to see if that keyword has been read previously during this run, if it is illegal with restart (if this is a restart run), or if it conflicts with another option already processed. Once this preliminary checking is complete, the program branches to the section of INPUT that reads the values given for the specified option. Here NXTVAR again is called to return the fields that comprise the values of the option. The syntax of the option is checked in addition to the value given. Numeric values are checked to be within specified limits and keywords must be one of a legal list of options.

Once all the option keywords have been processed, INPUT cross-checks all the selections to be sure that no information is missing or that conflicting options have not been chosen. INPUT issues two levels of error diagnostics. Warning messages are given when execution can proceed, but the user should be made aware of some possibly erroneous input data, such as an option specified twice. Fatal error diagnostics are issued when the input data is incomplete, in conflict, out of range, or contains syntax errors. Fatal errors will cause the CSPM run to be aborted. The PRINT routine is called to print the input data summary which lists all the options and values selected by the user or by default that will be used for this CSPM run. Finally, if a restart run has not been requested, the OPTIONS record is written to file LOSS and control is returned to the CSPM.

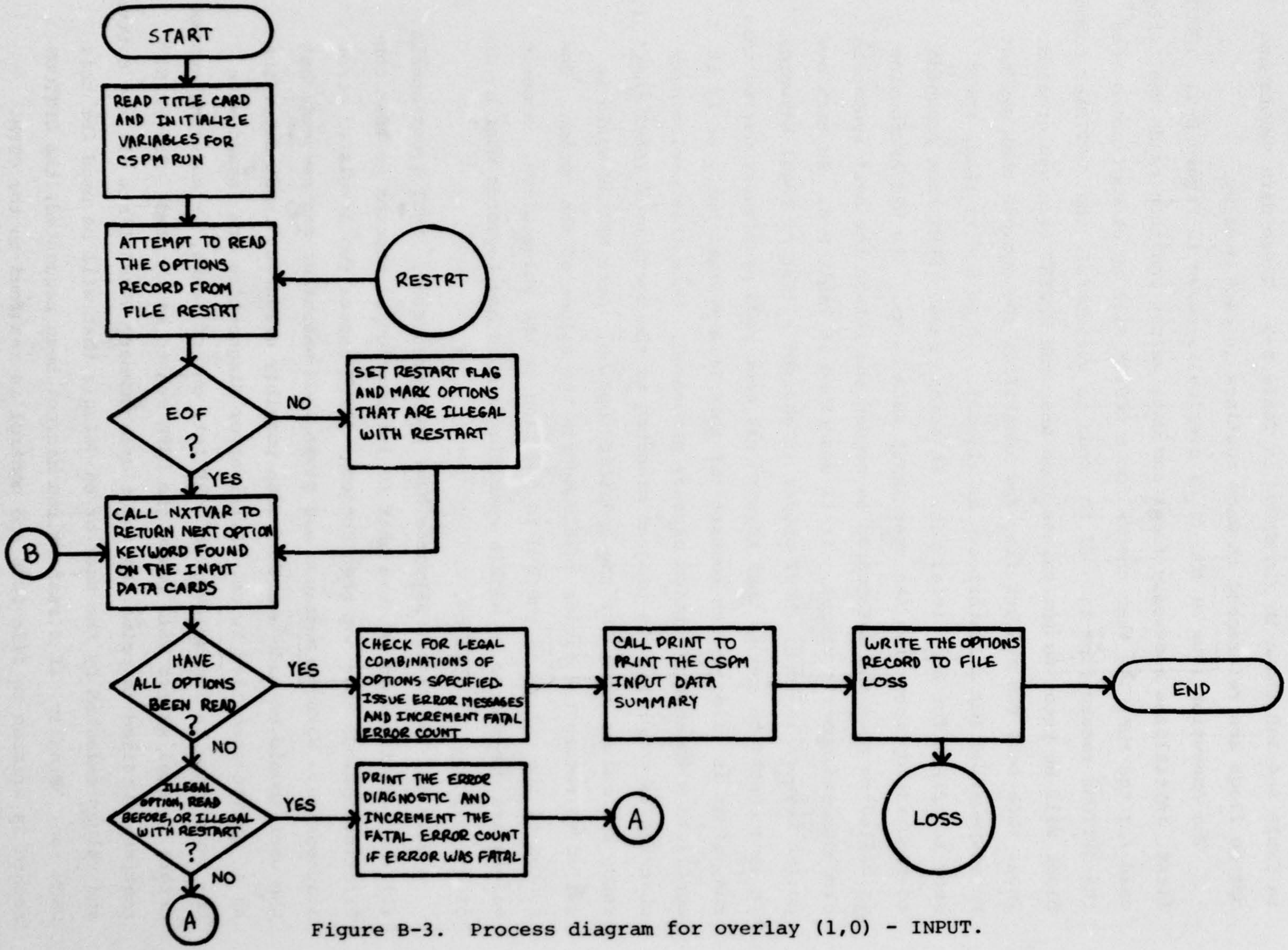

Figure B-3. Process diagram for overlay (1,0) - INPUT.

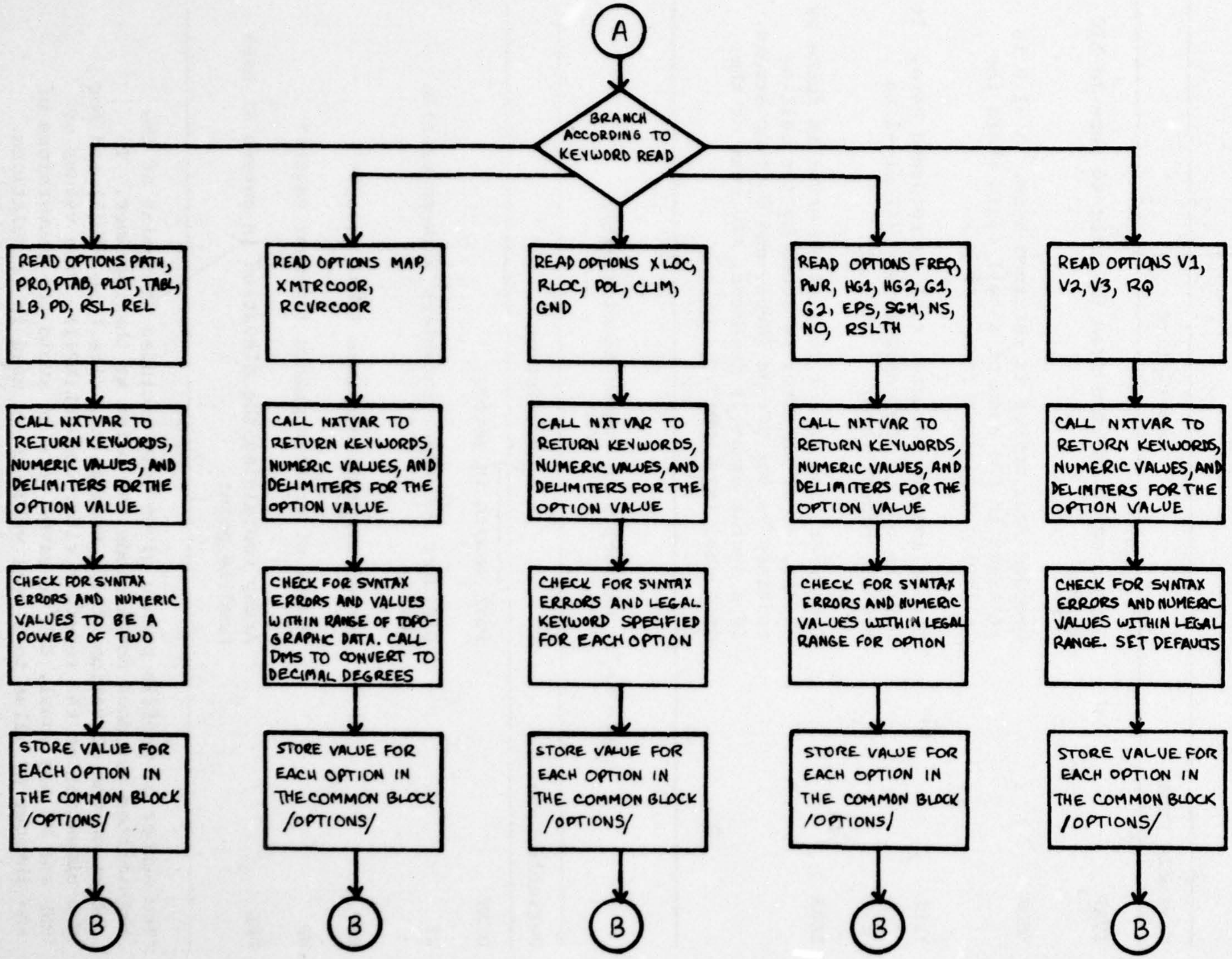

Figure B-3. Continued.

Table B-6. Variables in Common Block /NXTVAR/

Variable Name	Description
IVAR	Alphanumeric keyword read is returned here in A10 format.
XNUM	Decoded real number is returned here. A -1.0 is returned in the case of a null field where the following delimiter is a , or a).
IDEL	The delimeter character read is returned here. It must be one of the characters =,/() or -1 to signify end-of-card.
IERR	The error flag is set to 1 if an error is found by NXTVAR, -1 if an error is found by the calling routine, 99 for EOF on INPUT, and 0 if no errors. If a syntax error is detected, the rest of the data card is skipped.

Table B-7. Variables in Common Block /PFILE/

Variable Name	Description
DIST	Path length in meters.
XI	Distance increment in meters between profile points.
ENP	Number of profile points (real value)*
NP	Number of profile points (integer value)*
PFL	Array containing the elevation in meters at each profile point.

*The number of profile points given here includes the point at the transmitter but does not include the point at the receiver. To reference the elevation at the transmitter site, use PFL(1) and for the elevation at the receiver site, use PFL(NP+1). The values of ENP and NP are equal, ENP is saved here to avoid the conversions of the integer NP value to a real value to be used in calculations.

The flow diagram for the (2,0) overlay (figure B-4) explains the process of extracting path profiles and calculating ACR and statistical values with the Longley-Rice propagation prediction routines for a single path or points throughout a geographic area. The variables in common blocks /PFILE/ and /GEODYS/, described in Tables B-7 and B-8, are used to communicate with the path profile extraction routines. Common blocks /EVPARS/, /PHPARS/, and /SYPARS/ contain variables used to describe characteristics of the system and are used by the routines that calculate path parameter information. These common blocks are described in Tables B-9, B-10, and B-11. Notice that some of the same values that appear in these common blocks are repeated in the common blocks used with the Longley-Rice routines, /LRINP/, /LRDAS/, /LRVAR/, and /LRRTH/ which are described in Tables B-12, B-13, B-14, and B-15. Two separate cases are considered in LOSSMOD: one for a single path, and another for a geographic area.

If a single path has been specified, LOSSMOD first calls PFLTPO to extract path elevations from the topographic data base. Next, the path parameters for this path are calculated from the input data and the profile values by QPARS. Next, LOSSMOD sets a flag to tell the OUTPUT routine whether the path profile is to be plotted, tabulated, or plotted and tabulated. Next, the PROFILE record containing the output type flag, the path parameter values, and the profile elevations is written to file LOSS. (See Table B-2 for the structure of this record). LOSSMOD then checks to see if basic transmission loss has been requested for the path. If so, it transfers the necessary data values from the path parameter common blocks to those used by the Longley-Rice routines. These common blocks have not been combined, because the Longley-Rice routines can be replaced more easily with new versions if they are not modified in the CSPM. The climate-dependent variables are initialized by calling QVARLR with the climate code specified in the /OPTIONS/ common block. Next, QLRPP is used to initialize necessary variables for the Longley-Rice routines when used in the point-to-point mode. It also calls QACRLR to initialize the constants and the coefficients for the diffraction region. Next, LOSSMOD calls QQVARLR with the total path length to calculate the ACR and statistical values for the path. These values are returned in common block /LRVAR/. This information, needed to calculate LB for the path is written to file LOSS in an ACR DATA record (see Table B-2),

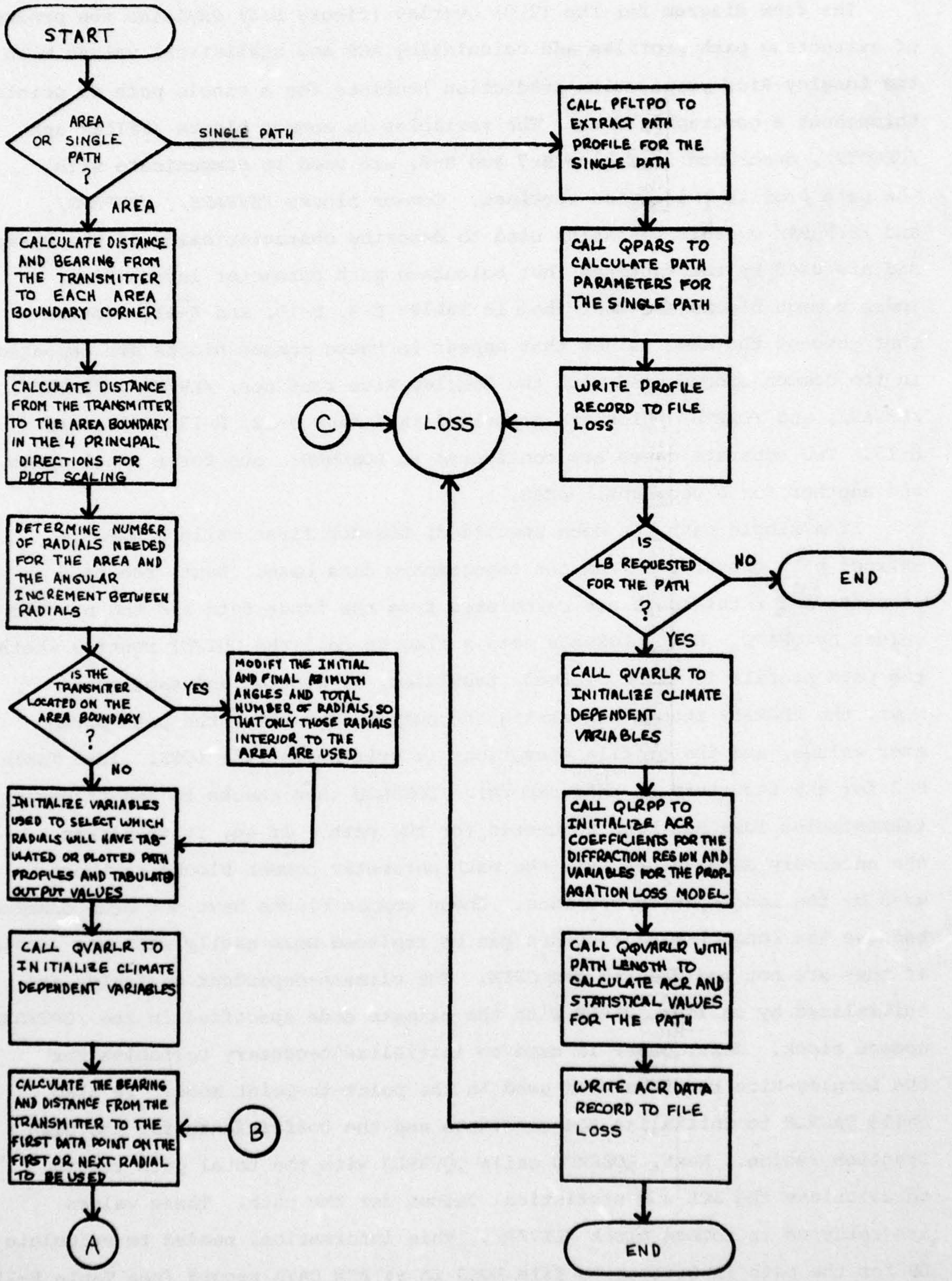

Figure B-4. Process diagram for overlay (2,0) - LOSSMOD.

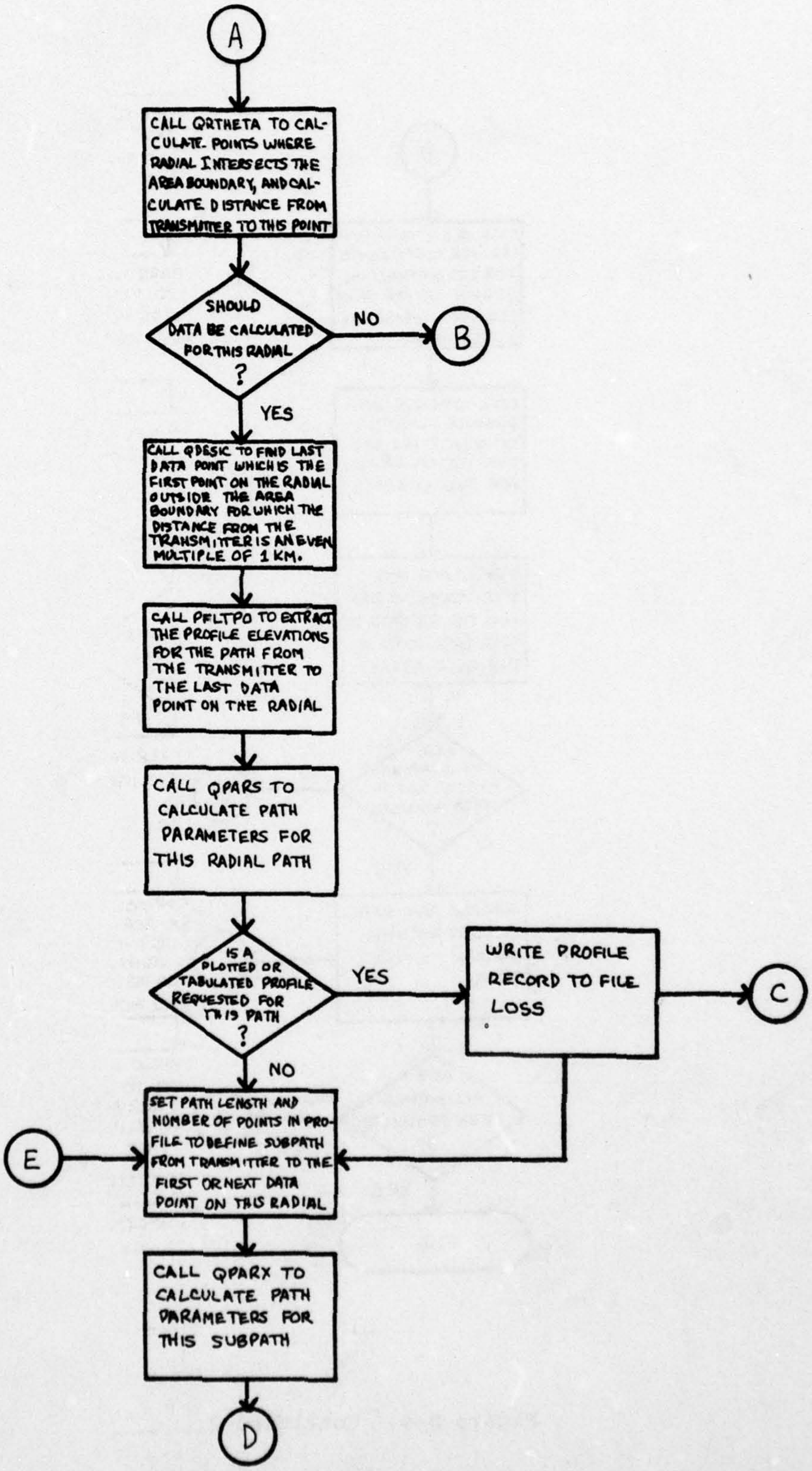

Figure B-4. Continued-1.

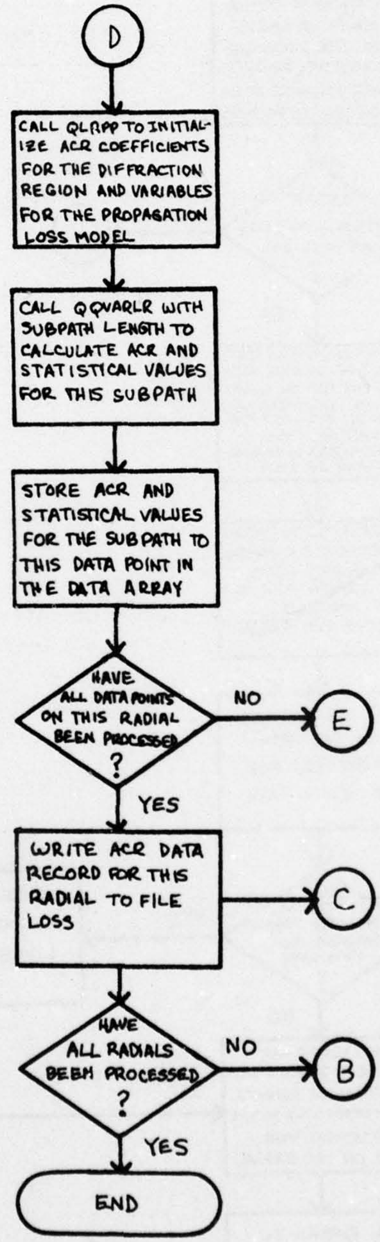

Figure B-4. Continued-2.

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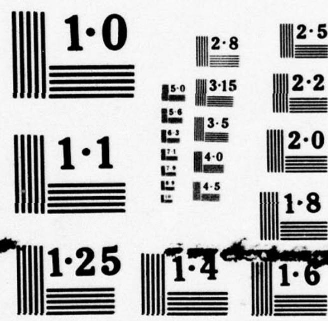

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Table B-8. Variables in Common Block /EVPARS/

Variable Name	Description
HSYS	The average of the transmitter and receiver site elevations above mean sea level in meters.
ENO	NO is the surface refractivity referenced to mean sea level.
ENS	NS is the surface refractivity.
RKFE	The effective earth radius coefficient.
GMFE	The curvature of the effective earth.
EPS	Ground dielectric constant.
SGM	Ground conductivity.
DLTH	Interdecile range of the terrain elevation in meters. *Delta H* is a measure of the terrain irregularity along a path.
HMSL(1)	Transmitter site elevation above mean sea level in meters.
HMSL(2)	Receiver site elevation above mean sea level in meters.

Table B-9. Variables in Common Block /PHPARS/

Variable Name	Description
DS	Path length in meters.
HSE(1)	Value returned from FFGND is the effective surface elevation in meters for the path from the transmitter to its horizon. It is determined by averaging the middle 80% of the profile elevations for the path.
HSE(2)	Value returned from FFGND is the effective surface elevation in meters for the path from the receiver to its horizon.
HSE(3)	Used by FFGND to calculate the effective surface elevation for the path from the transmitter horizon to the receiver horizon for double horizon paths.
HS(1)	The total height of the transmitter above mean sea level in meters calculated by summing the structural antenna height of the transmitter and the site elevation.
HS(2)	The total height of the receiver above mean sea level in meters calculated by summing the structural antenna height of the receiver and the site elevation.
HE(1)	The effective antenna height in meters of the transmitter which is the maximum of the structural antenna height of the transmitter or the difference between HS(1) and HSE(1).
HE(2)	The effective antenna height in meters of the receiver which is the maximum of the structural antenna height of the receiver or the difference between HS(2) and HSE(2).
ISO	Flag set to 0 if path is line-of-sight, 1 if double horizon, and -1 if single knife edge. This information presently is not used in the Longley-Rice model.
HL(1)	Transmitter horizon elevation in meters.

Table B-9. (Continued)

Variable Name	Description
HL(2)	Receiver horizon elevation in meters.
DL(1)	Distance from the transmitter to its horizon in meters.
DL(2)	Distance from the receiver to its horizon in meters.
THE(1)	Transmitter horizon elevation angle in radians.
THE(2)	Receiver horizon elevation angle in radians.
THEA	Sum of the horizon elevation angles.

Table B-10. Variables in Common Block /SYPARS/

Variable Name	Description
FMHZ	Carrier frequency in MHz.
WN	Wave number.
JPOL	Polarization of the transmitting antenna, set to 0 for horizontal or 1 for vertical polarization.
HG(1)	Transmitter structural antenna height in meters.
HG(2)	Receiver structural antenna height in meters.

Table B-11. Variables in Common Block /LRINP/

Variable Name	Description
DH	Terrain irregularity in meters.
FMHZ	Carrier frequency in MHz.
HG(1)	Transmitter structural antenna height in meters.
HG(2)	Receiver structural antenna height in meters.
HMSL(1)	Transmitter site elevation in meters.
HMSL(2)	Receiver site elevation in meters.
EPS	Ground dielectric constant.
SGM	Ground conductivity.
ENO	NO is the surface refractivity referenced to mean sea level.
ENS	NS is the surface refractivity.
KST(1)	Unused.
KST(2)	Unused.
KLIM	Code number for climate descriptor.
IPOL	Polarization of the transmitting antenna, set to 0 for horizontal and to 1 for vertical polarization.

Table B-12. Variables in Common Block /LRDAS/

Variable Name	Description
HE(1)	The effective antenna height in meters of the transmitter; value is the maximum of the structural antenna height of the transmitter and the difference between the total height of the transmitter above mean sea level and the effective surface elevation for the transmitter.
HE(2)	The effective antenna height in meters of the receiver; value is the maximum of the structural antenna height of the receiver and the difference between the total height of the receiver above mean sea level and the effective surface elevation for the receiver.
THE(1)	Transmitter horizon elevation angle in radians.
THE(2)	Receiver horizon elevation angle in radians.
THA	Sum of the horizon elevation angles.
HZ(1)	Transmitter effective antenna height that includes a complex factor to compensate for ground wave effects.
HZ(2)	Receiver effective antenna height that includes a complex factor to compensate for ground wave effects.
DL(1)	Distance from the transmitter to its horizon in meters.
DL(2)	Distance from the receiver to its horizon in meters.
DLA	Sum of the distances in meters to the transmitter and receiver horizons.
DLS(1)	Distance from the transmitter to its horizon in meters over a smooth earth.
DLS(2)	Distance from the receiver to its horizon in meters over a smooth earth.
DLSA	Sum of the distances in meters to the transmitter and receiver horizons over a smooth earth.

Table B-13. Variables in Common Block /LRVAR/

Variable Name	Description
XLBF	Free space loss in dB.
ACRV	A predicted reference value of attenuation below free space in dB.
VMD	The median time deviation above reference loss.
SGC	Standard deviation of prediction error.
SGL	Standard deviation of predicted attenuation due to location variability.
SGTM	Standard deviation of predicted attenuation for time variabilities less than the median value.
SGTP	Standard deviation of predicted attenuation for time variabilities greater than the median value.
SGTD	Standard deviation of predicted attenuation due to time variabilities for the ducting range.
ZD	Standard normal deviate of predicted attenuation for small time variabilities, such as are associated with the ducting phenomenon.
YD	The ducting range breakpoint, ZD*SGTP.

Table B-14. Variables in Common Block /LRRTH/

Variable Name	Description
AE	The effective earth's radius.
RKFE	The effective earth's radius coefficient.
GMFE	The inverse of the effective earth's radius.
ZGND	The surface transfer impedance (complex).
WN	Wave number.
CD	A filtering constant for diffraction weights. For known paths, such as in the CSPM, it is set to 10.
WAE	A normalized earth's radius.

Table B-15. Variables in Common Block /LBREL/

Variable Name	Description
STDIST	Distance in kilometers from the transmitter to the first data point along a map radial.
AZIM	Bearing of the path in decimal degrees clockwise from north.
NP	Number of data points on this path.
XLOSS	Array containing basic transmission loss values at each data point on the path for all three sets of variability statistics.
XREL	Array containing communication reliability values for each data point on the path for all three sets of variability statistics.
DATA	Array used for ACR data values.

and control is returned to CSPM.

The procedure followed for calculating values for a geographic area repeats the process used for a single path for each data point in the area. LOSSMOD calls QVARLR at the beginning to initialize climate-dependent variables for the map area. The method used to select the data points over the geographic area is described in Appendix F. Basically, it involves determining how many radials will be required to adequately cover the area and then using the system described in Table F-1 to locate data points along each radial. LOSSMOD determines the number of radials to be used by calculating the maximum distance from the transmitter to any point on the map boundary. The number of radials is then equal to the largest power of two that is less than this maximum distance. Once the number of radials has been determined, the angular increment between radials can be calculated. It is also necessary to consider the case in which the transmitter is not interior to the area boundary, but lies on a side or in a corner of the boundary. In this case, radials are not generated for a full 360°, but the initial and final bearings are restricted, so that all radials generated will be within the area. LOSSMOD loops through all the radials to be used for the area. A radial may be skipped if no contour plots have been requested, and the data on the radial are not to be tabulated. If contour plots have been selected, data for each radial must be calculated and written to file LOSS, so that the entire geographic area will be covered with data points.

Each radial is considered to be like a series of single paths, one from the transmitter to each data point along the radial. The distance between the transmitter and the first data point to be used on that radial is determined according to the method shown in Table F-1. To insure that the contour plots will be accurate, close to the area boundary, one extra data point outside the boundary is calculated for each radial. This point is determined by using QRTHETA to find the point where the radial intersects the boundary, to find the distance from the transmitter to that point, and then to round that distance to the nearest kilometer and find the point along the radial at that rounded distance from the transmitter using QRDESIC. Data points then will be calculated at one kilometer intervals along the radial from the starting point to the final point outside the box. PFLTPO is called to extract the path profile for the path from the transmitter

to the final data point. The point spacing, for path elevations, is fixed at 250 m, since the path length is always an even number of kilometers. Thus, the profile can be used in sections (four points to a kilometer) to provide the profile data for any one of the subpaths from the transmitter to a data point without calling the profile extraction routines each time. QPARS is used to calculate the path parameters for the entire radial path. If the profile for this radial is to be tabulated or plotted, a PROFILE record is written to file LOSS. LOSSMOD then loops through all the subpaths for this radial calling QPARX to calculate the path parameters for the profile values between the transmitter and each data point. Next, QLRPP is called to initialize the diffraction range coefficients for the path and to set values for the propagation loss calculation. Finally, QQVARLR is called with the distance from the transmitter to the data point to calculate the ACR and statistical values at that point. These are stored in the DATA array. When all data points for that radial have been processed, the ACR DATA record for that radial is written to file LOSS. This process continues until the data values have been calculated for all the map radials. The LOSS file then contains all the necessary data to plot or tabulate basic transmission loss, power density, received signal level, or communication reliability for the geographic area and control returns to CSPM.

Figure B-5 explains the execution flow of the (3,0) OUTPUT overlay. When an initial run has been made (not a restart run), OUTPUT rewinds the LOSS file and skips the OPTIONS record positioning to read the PROFILE and ACR DATA records that follow. If this is a restart run, the file RESTRT is read, and INPUT already will have read the OPTIONS record, so no positioning is needed. Next, OUTPUT calls QERFI to calculate the standard normal deviates for the variability sets to be used. It also calculates the power density and received signal level constants that are added to basic transmission loss to calculate power density and received signal level values. OUTPUT then reads each record from file LOSS or RESTRT until an EOF is found. If the record read is a PROFILE record, PRTAB is called to tabulate or plot the profile data. If this is a restart run, all PROFILE records are skipped. If the record read is an ACR DATA record and the run is for a single path, the basic transmission loss for each variability set specified is calculated and printed, and control returns to CSPM. For a geographic area, the

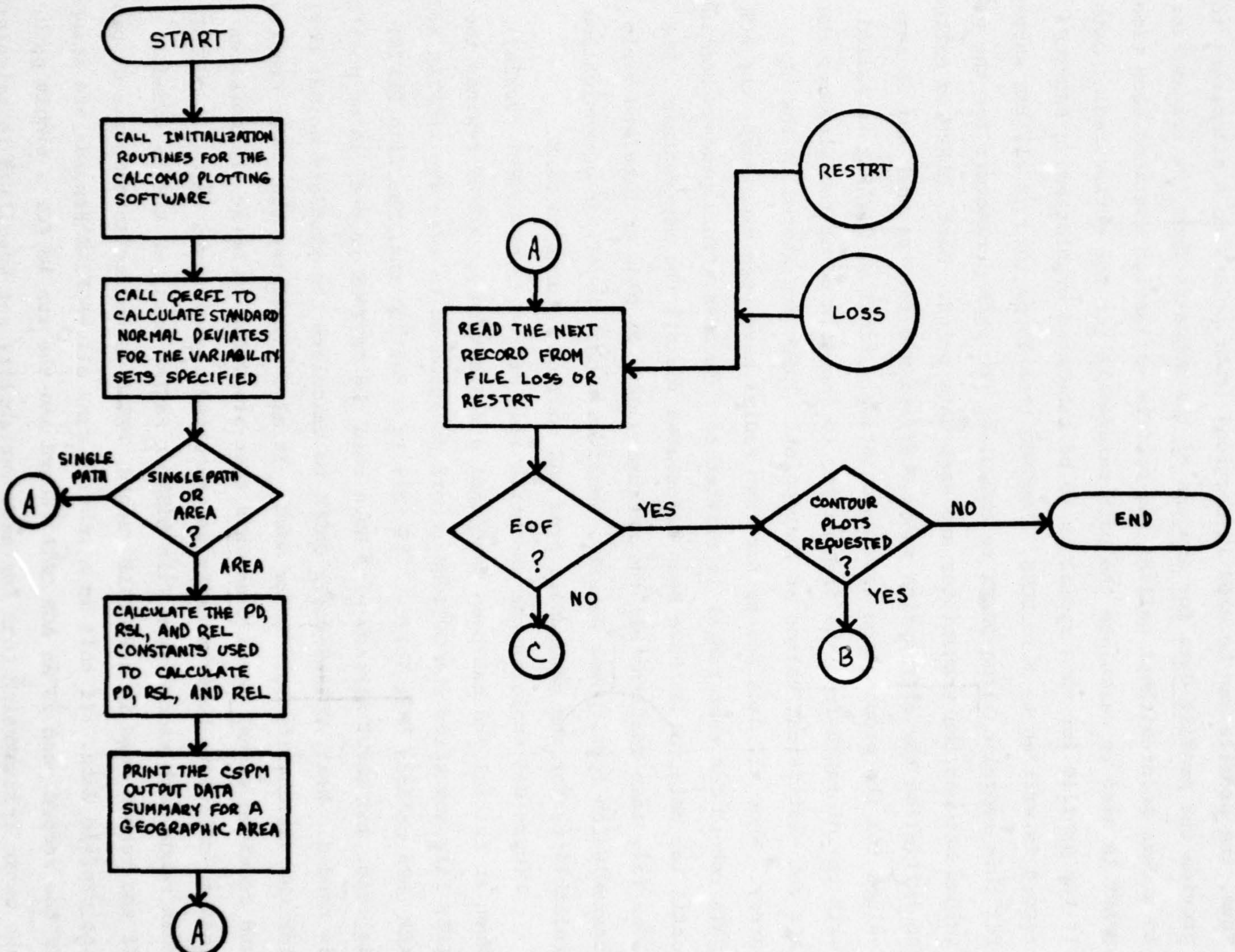

Figure B-5. Process diagram for overlay (3,0) - OUTPUT.

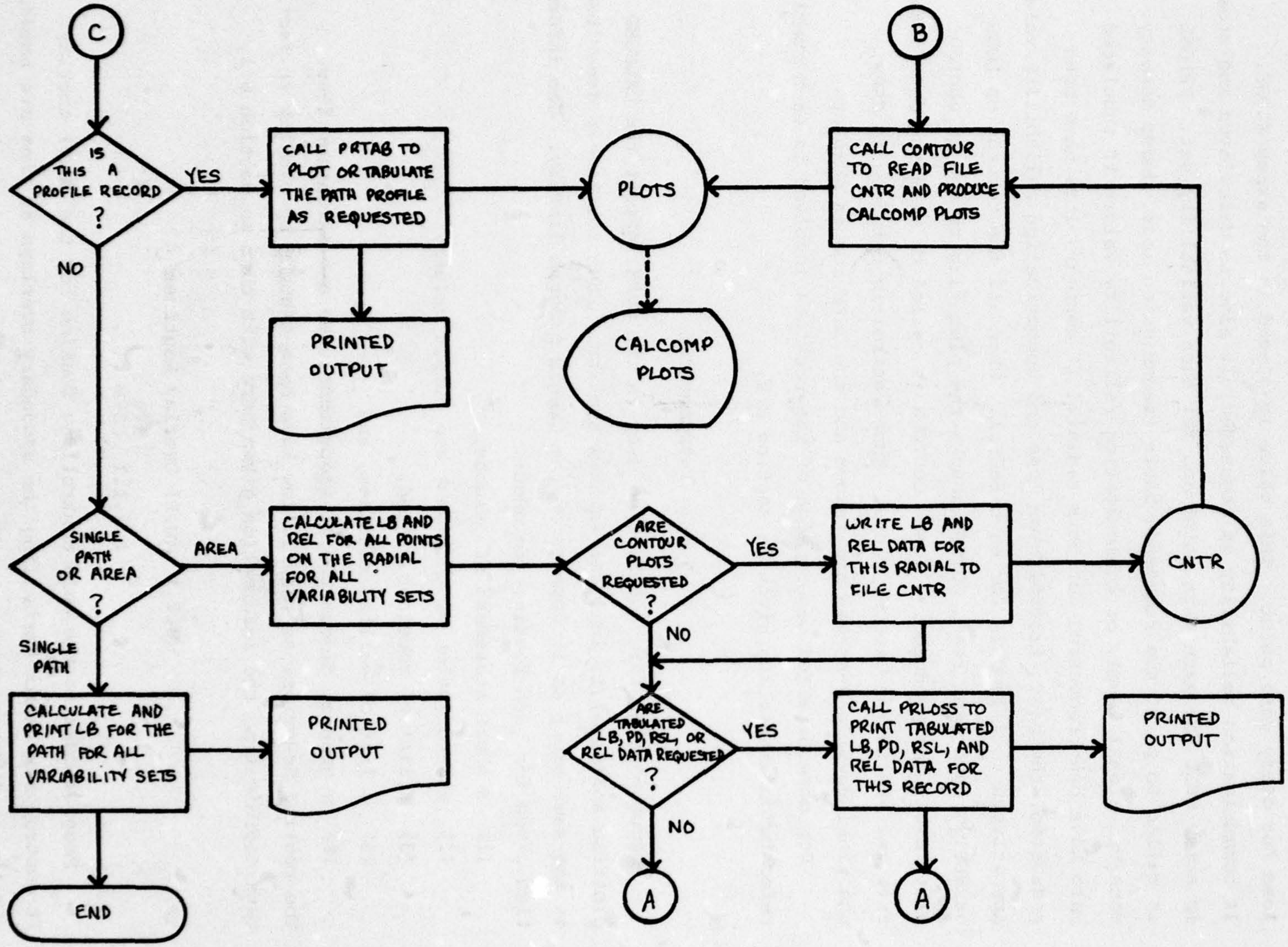

Figure B-5. Continued.

ACR DATA record contains the values necessary to calculate basic transmission loss for every data point. This value is stored in the array XLOSS. If communication reliability is requested, it also is calculated and stored in array XREL for each data point and for each variability set. PRLOSS is called to print the requested basic transmission loss, power density, received signal level, or communication reliability values if tabulated data have been requested for this radial. If contour plots have been requested, the basic transmission loss and communication reliability values are written to file CNTR for each radial. When all the records on LOSS or RESTRT have been read, OUTPUT checks the plot flag to see if contour plots are to be produced. If so, CONTOUR is called to read the CNTR data file and create the CALCOMP plots. When control is returned to CSPM, the final dayfile messages are issued and the CSPM run is complete.

For more detailed description of the routines involved in each overlay, refer to documentation given in section B.2.

B.2 Introduction

Documentation for each routine used in the CSPM (except the CALCOMP plotting software) is included in this section. Each routine is described in the same order as it appears on the UPDATE program library. The information given for each routine includes:

(1) a short statement of purpose,

(2) a description of the input and output values,

(3) a list of routines called,

(4) a list of calling routines, and

(5) a general discussion of algorithms used and execution flow.

The routine descriptions that follow have been grouped by overlay to facilitate coordinating the information given here with that in section B.1.

B.2.1 (0,0) Overlay Routines

B.2.1.1 CSPM

Program CSPM is the main controlling routine for the (0,0) overlay. It controls execution by calling the secondary overlays as they are needed and issues the CSPM dayfile messages.

FILES

The files used by CSPM are listed in Table B-1. CSPM does not attach or catalog any files. The user must include the appropriate control cards in his deck to attach a RESTRT file, catalog a LOSS file, or dispose a PLOT file to the CALCOMP plotter. The record structures for files LOSS (RESTRT) and CNTR are given in Tables B-2 and B-3.

COMMON BLOCKS

CSPM defines two common blocks that are used to store options and data values used in more than one overlay. Tables B-4 and B-5 describe the variables included in the /OPTIONS/ and /LOSSMOD/ common blocks.

ROUTINES CALLED

CSPM calls the following routines:

INPUT

LOSSMOD

OUTPUT

PROGRAM DESCRIPTION

CSPM displays information about the number of fatal errors found, the number of plots generated, and the execution time for the run in dayfile messages. It initially calls the system routine SECOND to return the starting CP time. At the end of the run, it again calls SECOND to obtain the final CP time and then displays the execution time for the run in seconds in the dayfile. If fatal errors are encountered during input processing or topographic data extraction, the number of errors is displayed and the run aborted. If plotted path profiles or contour plots have been requested, the number of plots generated by this CSPM run on file PLOT also will be displayed. When the run is complete, the final dayfile message is issued to inform the user that the CSPM terminated normally.

CSPM controls the execution flow by calling the secondary overlays in the following order. The INPUT (1,0) overlay is called to read the user input data cards and check for a restart file. If any fatal errors are detected during input processing, CSPM displays the number of errors in a dayfile message and aborts the run. If no errors are found, CSPM checks the restart flag to determine if the LOSS (2,0) overlay should be called. If a RESTRT file has not been provided, LOSSMOD is called

to extract path profiles and generate ACR and statistical data for a single path or data points over a geographic area. If fatal errors are encountered during the profile extraction due to missing data on the topographic data base, CSPM aborts the run. When all the data have been calculated and written to file LOSS, CSPM calls the OUTPUT (3,0) overlay to read the LOSS file and produce the requested tabulated and plotted output. If this is a restart run, OUTPUT reads the data from file RESTRT, since no new LOSS file has been generated. When CSPM has finished executing, it is the user's responsibility to dispose the PLOT file to the CALCOMP plotter and save the LOSS file for use in future restart runs.

B.2.1.2 HEADER

Subroutine HEADER prints the two line page heading on every page of the CSPM output.

ARGUMENTS

NLINES - Number of lines to be printed by the calling routine. If this number is greater than the number of lines left on the page, a page eject is issued and the page header is printed. A new page may be requested by the calling program by setting NLINES = -1.

ROUTINES CALLED

None.

CALLED BY

HEADER is called by all CSPM routines that print formatted output.

LOCAL VARIABLES

NPAGE - Last page number printed.

MAXL - Maximum number of lines printed per page.

NUM - Number of lines already printed on the current page.

SUBROUTINE DESCRIPTION

HEADER can be used in two ways. Normally, it is called whenever a routine is about to print one or more lines that should appear on the same page, to insure that space will be available. However, if a table is being printed that extends over more than one page, it is more efficient for the calling routine to count locally the number of lines on the page and

only call HEADER when the current page is filled. This scheme enables the calling routine to print titles for the columns on each page. HEADER is called with NLINES = -1 whenever it is desirable to begin printing on a new page.

B.2.2 (1,0) Overlay Routines

B.2.2.1 INPUT

Program INPUT is the controlling routine for the (1,0) overlay. It calls NXTVAR to read options from the CSPM input data cards, checks them for errors, stores flags and data values in common block /OPTIONS/ (see Table B-4), and calls PRINT to print the CSPM input data summary. It also determines if a restart file is available and if so, sets the proper variables. If restart has not been selected, INPUT writes the OPTIONS record (see table B-2) to file LOSS.

<u>COMMON BLOCKS</u>

INPUT defines the common block /NXTVAR/ which is used to communicate with the routine NXTVAR. It is described in Table B-5.

<u>ROUTINES CALLED</u>

INPUT calls the following routines:

- DMS.
- HEADER.
- NXTVAR.
- PRINT.

<u>CALLED BY</u>

INPUT is called by CSPM.

<u>LOCAL VARIABLES</u>

KEYWORD	Array containing list of legal keywords.
NKEY	Number of legal keywords.
KFLAG	Set to 0 if keyword has not yet been read, to -1 if keyword is illegal for a restart run, to 1 if keyword has been read.
JTITLE	Title of restart run.
JDATE	Date of restart run.

JTIME	Time of restart run.
IVAL	Array equivalenced to integer variables in /OPTIONS/.
NAME	Array equivalenced to Hollerith variables in /OPTIONS/.
VAL	Array equivalenced to real variables in /OPTIONS/.
X	Array used for latitude-longitude coordinates.
GROUND	Array containing legal values for option GND.
GNDDAT	Array containing values of SGM/EPS for GND type.
DRQ	Default values for RQ.
VLIM	Range limits for real variables in /OPTIONS/.
KUNITS	Units for real variables in /OPTIONS/.

PROGRAM DESCRIPTION

INPUT controls the reading and processing of user input options. It first initializes necessary flags and data values and then reads the title card for the run. INPUT then checks for a RESTRT file by attempting to read the OPTIONS record from it. If the read is successful, the /OPTIONS/ common block will be reset to the values used when the RESTRT file was created. INPUT then sets the restart flag and identifies the options that may not be respecified for a restart run as illegal. If an EOF is read, INPUT sets the flags for an initial run. In either case, INPUT then proceeds to read the options from the user input data cards. It calls NXTVAR to read data cards as needed and return the next syntactic element it finds (keyword, numeric value, or delimiter). As each new option keyword is read, it is checked against a list of legal options. INPUT also checks to see if that option has been specified previously during the run, if the option is illegal with restart (if a restart run has been specified), or if the option conflicts with another option previously read. Once this preliminary checking is completed, the program branches to the section of INPUT that reads the values given for the selected option. Separate processing sections are used for the following groups of options:

(1) PATH, PRO, PTAB, PLOT, TABL, LB, PD, RSL, REL.

(2) MAP, XMTRCOOR, RCVRCOOR.

(3) XLOC, RLOC, POL, CLIM, GND.

(4) FREQ, PWR, HG1, HG2, G1, G2, EPS, SGM, NS, NO, RSLTH.

(5) V1, V2, V3, RQ.

NXTVAR is used to return the fields that correspond to the values of the option. The syntax of the option is checked in addition to the value given. Numeric values are checked to be within specified limits, and keywords must be one of a legal list of options. Once all the option keywords have been processed from the user input data cards, INPUT cross-checks all the selections to be sure that no information is missing and that no conflicting options have been chosen. INPUT issues both warning and fatal error diagnostics. Warning messages are given when execution can continue, but the user should be made aware of some possibly erroneous input data. Fatal error diagnostics are issued when the input data is incomplete, in conflict, out of range, or contains syntax errors. Fatal errors will cause the CSPM run to be aborted. The PRINT routine then is called to print the input data summary which lists all the options and values selected by the user together with the default values that will be used for this CSPM run. Finally, if the run is not a restart run, the OPTIONS record is written to file LOSS, and control is returned to CSPM.

B.2.2.2 DMS

Subroutine DMS converts a latitude-longitude coordinate in decimal degrees north and east to a Hollerith encoded format ready to print in positive degrees/minutes/seconds and decimal degrees with the proper direction North, South, East, and West appended.

ARGUMENTS

N	Number of arguments to be encoded (2 or 4).
ZLAT	Latitude in decimal degrees north.
ZLON	Longitude in decimal degrees east.
YLAT	Second latitude if map boundary is input.
YLON	Second longitude if map boundary is input.
IDMS	Array returned with positive degrees/minutes/seconds and proper direction for latitude and longitude values input in Hollerith format.
IDEC	Array returned with positive decimal degrees and proper direction for latitude and longitude values input in Hollerith format.

ROUTINES CALLED

None.

CALLED BY

DMS is called by INPUT.

PROGRAM DESCRIPTION

DMS is used to convert the latitude and longitude values for the transmitter and receiver coordinates from decimal degrees north and east to an encoded Hollerith format ready for printing. The latitude and longitude boundaries for a map also are encoded by DMS into a print-ready format. DMS initially takes the absolute value of the latitude or longitude in decimal degrees and determines the proper direction North, South, East, or West to be used with the positive value. The decimal degrees format then is encoded into array IDEC. DMS then converts the decimal degrees to degrees/minutes/seconds format and encodes these values into array IDMS.

B.2.2.3 NXTVAR

NXTVAR is used to read the free-format user input data cards. It reads successive data cards until an EOF is found. Each card is printed when it is read, so that error messages pertaining to options on that card will immediately follow the card image. On each call to NXTVAR, the next keyword or numeric value along with the following delimiter is returned. If the variable read is not of the type requested, an error message is printed and the error flag is set. All 80 columns of the data card are processed. Blanks are ignored. The five characters =,/() and the end of the card are recognized as delimiters. The first nonnumeric character following a numeric field also is considered to be a delimiter. Integer values are returned as real numbers. If a syntax error is found, the rest of the data card is skipped. Multiple input values may be given on a single data card, but a single input definition may not span card boundaries.

ARGUMENTS

ITYPE	The type of variable expected. Set to one for keyword, two for numeric value, and three for delimiter. If the variable field read does not match the type expected by

the calling routine, an error message is printed, and the error flag is set.

COMMON BLOCKS

Common block /NXTVAR/ is used to return the alphanumeric keywords, numeric values, and delimiters read as well as an error flag. The variables in this common block are described in Table B-5.

ROUTINES CALLED

NXTVAR calls the routine HEADER.

CALLED BY

NXTVAR is called by INPUT.

LOCAL VARIABLES

ICARD	Array containing the input data card being processed in 80 R1 format.
ICOL	Pointer set to the position of the last character used from ICARD.
JVAR	Characters read from ICARD are packed into JVAR until a delimiter is found. The variable is encoded later into IVAR if it is a keyword, or decoded into XNUM if it is determined to be a numeric value.

The following flags are used to decide the type of the variable read and to diagnose errors:

JALPHA	Nonzero if a nonnumeric character is packed into JVAR.
JDECPT	Number of decimal points in JVAR.
JPLUS	Number of plus signs in JVAR.
JMINUS	Number of minus signs in JVAR.
JFIRST	First nonblank character read.
KNT	Number of characters read before a delimiter is found.

PROGRAM DESCRIPTION

NXTVAR is called to return one syntactical element at a time except in the case of an alphanumeric or numeric field in which case the following delimiter also is returned to the calling routine. This enables the INPUT program to look only at the syntax of the options and their values without being concerned about skipping blanks, reading the next card, or determining

if characters in a field are a keyword, a real number, an integer, or a delimiter. NXTVAR reads a data card into the array ICARD in 80 R1 format when all characters on the previous card have been processed. It looks for the next syntactic element by taking successive characters from the last column position processed on the last card toward the end of the card until a delimiter is found or more than 10 characters are processed. These characters are packed into variable JVAR. While each character from ICARD is being processed, certain information is kept about the type of characters found. Blanks are ignored and are not put into JVAR. If a minus, plus, or decimal point is found, the value of the field must be numeric. Only one of each of these characters may appear in one field, or an error will be diagnosed. If the first nonblank character in a field is alpha, then the field must be a keyword. Keywords are returned in A10 format in the variable IVAR. Numeric fields are decoded into a real numeric value and returned in the variable XNUM. Delimiter characters that are found are returned in R1 format in the variable IDEL. The error flag IERR will be zero if no errors are diagnosed, and one if an error is found.

B.2.2.4 PRINT

Subroutine PRINT prints the CSPM input data summary. All the values that it prints have been stored previously in common block /OPTIONS/. They are described in Table B-4.

ARGUMENTS

None.

ROUTINES CALLED

PRINT calls the routine HEADER.

CALLED BY

PRINT is called by the INPUT routine.

SUBROUTINE DESCRIPTION

PRINT is called to print the CSPM input data summary after all the user input options have been read and processed. The data values and option flags selected by the user together with the default values set by the CSPM are printed in the input data summary, so that the user will have a complete

record of all values used in this CSPM run. All the necessary data for PRINT to print are stored in the /OPTIONS/ common block. The values that are printed depend on the type of output selections made. The format also varies between runs for a single path and those for analyzing a geographic area.

B.2.3 (2,0) Overlay Routines

B.2.3.1 LOSSMOD

Program LOSSMOD is the controlling routine for the (2,0) overlay. It controls the process of extracting path profiles from the topographic data base and calculating ACR and statistical values with the Longley-Rice propagation prediction routines for a single path or points throughout a geographic area. If plotted or tabulated path profiles have been requested, the path elevations are written to file LOSS to be used by the OUTPUT (3,0) overlay. If basic transmission loss has been requested for a single path, or basic transmission loss, power density, received signal level, or communication reliability data have been requested for contour plots or tabulated output, the ACR DATA records for the necessary paths also are written to file LOSS.

COMMON BLOCKS

LOSSMOD uses many common blocks to communicate values with other routines. It references the input data values and option flags stored in the /OPTIONS/ common block and generates the values to be passed to the OUTPUT overlay in the /LOSSMOD/ common block. These are described in Tables B-4 and B-5 The variables in common blocks /PFILE/ and /GEODYS/ described in Tables B-7 and B-8 are used to communicate with the path profile extraction routines. Common blocks /EVPARS/, /PHPARS/, and /SYPARS/ contain variables used to describe characteristics of the system and are used by the routines that calculate path parameter information. These common blocks are described in Tables B-9, B-10, and B-11. Notice that some of the same values that appear in these common blocks are repeated in the common blocks used with the Longley-Rice propagation loss routines, /LRINP/, /LRDAS/, LRVAR/, and LRRTH/ which are described in Tables B-12, B-13, B-14, and B-15. Because the Longley-Rice propagation loss prediction routines that are used in the CSPM may be replaced at a future time, it is considered necessary to

keep their common blocks intact. Consequently, the path parameter and system information contained in common blocks /OPTIONS/, /EVPARS/, /PHPARS/, and /SYPARS/ simply is transferred to the proper position in the Longley-Rice model common blocks before those routines are called.

ROUTINES CALLED

LOSSMOD calls the following routines:

PFLTPO

DESIC

QLRPP (entry point in QLRAP)

QPARS (and the alternate entry point QPARX)

ARDESIC

QRTHETA

QVARLR (and the alternate entry point QQVARLR).

CALLED BY

LOSSMOD is called by CSPM.

PROGRAM DESCRIPTION

LOSSMOD is used to extract path profiles, calculate path parameter information, and calculate the ACR and statistical data for either a single path or for points throughout a geographic area. This information is written to file LOSS and later is used by the (3,0) overlay, OUTPUT, to produce tabulated and plotted path profiles and tabulate output or contour plots for basic transmission loss, power density, received signal level, and communication reliability.

If a single path has been specified, LOSSMOD first calls PFLTPO to extract the path profile elevations from the topographic data base. Next, QPARS is called to calculate the path parameters from the input data in /OPTIONS/ and the path profile elevations in /PFILE/. Next, LOSSMOD sets a flag to tell the OUTPUT routine whether the path profile is to be plotted, tabulated, or plotted and tabulated. Then the PROFILE record containing the output type flag, the path parameter values, and the profile elevations is written to file LOSS. See Table B-2 for the structure of this record. LOSSMOD then determines if basic transmission loss has been requested for the path. If so, it transfers the necessary data values from the path parameter common blocks to those used by the Longley-Rice propagation loss

routines. The climate dependent variables are initialized by calling QVARLR with the climate code specified in the /OPTIONS/ common block. Next, QLRPP is called to initialize necessary variables used in the propagation loss routines for the point-to-point mode and to calculate the ACR coefficients for the diffraction region. LOSSMOD then calls QQVARLR with the total path length to calculate the ACR and statistical values for the path. These values are returned in the common block /LRVAR/. This information is written to file LOSS as an ACR DATA record in the format described in Table B-2. Control then is returned to CSPM.

The procedure followed for calculating values for a geographic area repeats the process used for a single path for each data point in the area. LOSSMOD first calls QVARLR to initialize the climate dependent variables for the area being studied. The data points to be used throughout the geographic area are selected by the method described in Appendix F. Basically, the method involves determining how many radials are required to adequately cover the area and then using the system described in Table F-1 to locate data points along each radial. To determine the number of radials to be used, LOSSMOD first calculates the maximum distance from the transmitter to any point on the area boundary. The number of radials to be used is then equal to the largest power of two that is less than this maximum distance. Once the number of radials has been determined, the angular increment between radials is calculated. If the transmitter is located on the area boundary, the initial and final angular values are restricted, so that only those radials that are interior to the area are used.

LOSSMOD loops through all radials used for the area. A radial is skipped if its data values are not to be tabulated and no contour plots have been requested. If any contour plots have been selected, data are generated for all radials so that the spacing of data points will be uniform across the entire area. ACR and statistical values are generated for each data point along the radial. This is done by considering each radial to be like a series of single paths from the transmitter to each data point on the radial. The distance between the transmitter and the first data point to be used on that radial is determined according to the method shown in Table F-1. To insure that the contour plots will be accurate close to the area boundary, one extra data point outside the boundary is used

for each radial. The location of this point is determined by using QRTHETA to find the point where the radial intersects the boundary, calculating the distance from the transmitter to that point, rounding that distance up to the nearest kilometer, and calling QRDESIC to calculate the coordinates of the point that lies on the radial at that distance from the transmitter. Data points are distributed then at one kilometer intervals along the radial from the starting point to the final point outside the boundary. For any radial, if the distance to the starting data point is greater than the distance to the boundary, the radial is skipped.

PFLTPO is called to extract the path profile from the topographic data base for the path from the transmitter to the final data point outside the boundary. The point spacing on the profile is fixed at 250 m, since the path length is always an even number of kilometers. Thus, the profile can be used in sections (four points to a kilometer) to provide the profile data for any one of the subpaths from the transmitter to a data point. QPARS is called to calculate the path parameters for the entire radial path. If the profile for this radial has been selected to be tabulated or plotted, a PROFILE record is written to file LOSS.

LOSSMOD then loops through all the subpaths for this radial calling QPARX to calculate the path parameters for the profile values between the transmitter and each data point. QPARX is an entry point in QPARS that approximates ΔH for the subpath rather than calculating the actual inter-decile range of the profile elevations. Next, QLRPP is called to initialize the diffraction range coefficients for the path and to set values for the point-to-point mode propagation loss routines. Finally, QQVARLR is called with the distance from the transmitter to the data point (the length of the subpath) to calculate the ACR and statistical values at the data point. These values are stored in the DATA array. When all the data points for this radial have been processed, the ACR DATA record for the radial is written to file LOSS. This process continues until the data values have been calculated for all the radials throughout the area. The LOSS file then contains all necessary data to plot or tabulate basic transmission loss, power density, received signal level, or communication reliability for the geographic area, and control is returned to CSPM.

B.2.3.2 ELVTPO

Function ELVTPO returns the elevation in meters for a point within range of the topographic data base. The elevation is determined by using bivariate linear interpolation between the four surrounding data points on the topographic data base.

ARGUMENTS

ALAT Latitude of the point in decimal degrees north.

ALON Longitude of the point in decimal degrees east.

IERR Error flag:

(0) no errors.

(1) parity error in index block.

(2) parity error in data block.

(8) missing data was filled in with an averaging technique.

(-1) point is out of range of the topographic data base.

(-2) data block is missing.

(-3) too many missing data points.

The principle here is that errors with negative codes are serious and the point is definitely unattainable, while positive error codes indicate that the data were obtained under suspicious circumstances. In the case of a positive error code an attempt is made to return a correct value, but for a negative code, there is no such attempt and the returned value is meaningless.

Furthermore, the routine is written in such a way that in a series of calls (as for example along a great circle path), the error return need be checked only at the end. The normal return leaves IERR unaffected which is why it should be set initially to 0. A positive error code is logically or'ed with IERR, and a negative code turns off all other attempts at making evaluations.

COMMON BLOCKS

/PKDTPO/ This common block is defined in subroutine LDDTPO.

ROUTINES CALLED

ELVTPO calls LDDTPO.

CALLED BY

ELVTPO is called by PFLTPO.

FUNCTION DESCRIPTION

Upon entry, the routine first assures that the proper 1° by 1° block is loaded in /PKDTPO/ using, if necessary, a call to LDDTPO. It then unpacks the elevations at the four corners of the 30" by 30" square within which the given point falls. The returned value is obtained using the standard bilinear interpolation between these four points.

If from one to three of the corner values are missing from the tape, they are filled with the simple average of the remaining corner values, and bit number 3 of IERR is set. If all four values are missing, then IERR is replaced by -3. If upon first entering the value of IERR is negative, the entire routine is skipped.

B.2.3.3 FFGND

Subroutine FFGND calculates an effective surface elevation for the terrain between the transmitting antenna and its horizon and for the terrain between the receiving antenna and its horizon for paths which are not line-of-sight. For a path that is determined to be line-of-sight, this subroutine calculates effective surface elevation for the terrain between the transmitting and receiving antennas. Effective surface elevation is defined as the average elevation for the middle 80% of the profile points comprising the path or path segment (as in the case of non line-of-sight paths).

ARGUMENTS

None.

COMMON BLOCKS

FFGND uses common blocks /PFILE/, defined in table B-7 and /PHPARS/, defined in Table B-10.

ROUTINES CALLED

None.

CALLED BY

FFGND is called by QPARS.

SUBROUTINE DESCRIPTION

FFGND calculates an effective elevation for the foreground of an antenna under certain conditions for which use of actual foreground elevation would result in propagation loss predictions which would be quite different from measured loss over that path. The calculation of effective foreground elevation is accomplished by first defining four variables which express the number of profile points from the transmitter to other locations along the path. The first variable, NL(1) ≡ 0, is the number of points to the transmitter location. The second variable, NL(2), is the number of points to the horizon for the transmitting antenna. The third variable, NL(3), is the number of points (from the transmitter) to the horizon for the receiving antenna. The fourth variable, NL(4), is the number of points (from the transmitter) to the receiver location. This value is, in fact, the number of points in the profile array.

These four variables are used to define segments of the path. The path segments of interest for a transhorizon path are the segments from the transmitting antenna to its horizon and the segment from the receiving antenna to its horizon. For a line-of-sight path, the entire path is considered. For each segment and the entire path, the middle 80% of the segment/path elevations are used to calculate an average elevation. A check is made on the value for variable ISO provided in common block /PHPARS/. When ISO=0, the path is line-of-sight. A value of 1 or -1 denotes a transhorizon path. The effective surface elevation(s) then is(are) returned to QPARS using variable HSE.

B.2.3.4 ISEARCH

Function ISEARCH returns the value of the smallest index at which the corresponding element in the array JA matches the word K. If no match is found, a zero is returned.

ARGUMENTS

K Contains the work for which a match in JA is being searched.
N Number of words to be searched in array JA.
JA Array of words to be searched.

ROUTINES CALLED

None.

CALLED BY

ISEARCH is called by LDDTPO.

FUNCTION DESCRIPTION

ISEARCH is an integer function. It loops through the first N elements of array JA looking for a match with K. If a match is found, ISEARCH returns the index value in array JA at which the matching value is stored. If no match is found, a zero is returned. JA and K may have either integer or Hollerith values.

B.2.3.5 LDDTPO

LDDTPO is the basic subroutine for reading the topographic data tapes. Given the latitude and longitude of the southwest corner of a data block, the routine finds the proper record and reads it into the common block /PKDTPO/. The data are still in packed form, but enough information is supplied to make extraction of the desired values reasonably easy. Most jobs require shuttling back and forth between two or more records. To increase efficiency and to reduce wear and tear on the topographic data tape, a mechanism is built in for saving and retrieving such records. A scratch file on disc is used in which up to ten records are stored. Normally, LDDTPO is not called directly by the user, but only indirectly through routine ELVTPO. This routine not only makes the proper calls to LDDTPO, but it also unpacks the data into immediately usable forms.

LDDTPO uses local file names TOPO, for the magnetic tape, and TOPS, for the scratch file. File TOPS is a word-addressable file which is handled automatically, hence it will not be discussed further. The statement

```
CALL LDDTPO(LAT,LON)
```

causes one particular record to be read. The variables LAT, LON are the latitude and longitude of the southwest corner of the desired data block. They are integers and give degrees measured north of the equator and east of the Greenwich meridian. In CONUS the latitude is positive and the longitude negative. The output is contained in the common block /PKDTPO/ which is

defined later in this section.

FILES

The files used by LDDTPO have been identified as TOPO and TOPS. File TOPO, containing the topographic data on magnetic tape, is described in Appendix E. As mentioned, TOPS is a word-addressable, scratch file to which blocks of data read from TOPO are written automatically.

ARGUMENTS

LAT	Latitude in decimal degrees north of the southwest corner of the requested data block.
LON	Longitude in decimal degrees east of the southwest corner of the requested data block.

COMMON BLOCKS

/PREFACE/	Contains information that was read from the tape header record by READPRF for the topographic data tape being used (file TOPO).
NNFO	Number of words of information contained in the topographic data tape header record.
FMT	Eight-word array containing the FTN FORMAT statement used by PRNTPRF to print the information contained in the header record.
TITLE	Four-word array containing the title of the topographic data tape.
LATP	Two-word array containing latitude range bounds for the topographic data tape.
LONP	Two-word array containing longitude range bounds for the topographic data tape.
KODE	Integer giving the key to format of the tape, type of data, etc. Must be =1 to be compatible with the CSPM.
JNFO	Eleven-word, unused array.
/PKDTPO/	Contains data read from the topographic data tape for a 1° by 1° block.
PKDN	A floating point number defined as 1.000001/n, where n is the number of data points packed into a word.

PKDF A floating point number defined as nb, where b is the number of bits used for a datum (2,3,4,5,6,7,8,10, or 12).

KXR A coded word which indicates parity errors realized in reading a record. Values are:

KXR = 0, No parity errors.

1, A parity error while reading the index record of the latitude data partition.

2, A parity error while reading the block data record.

3, Parity error in both records.

MSKD A mask of b 1's, right justified.

LPKD The number b of bits per datum.

NPKD Status indicator for the block data record. Values are:

NPKD = -2 The block is missing from the tape.

= -1 The block is outside the range of the tape.

= 0 The block is ocean.

= n>0 Data for the block are on the tape and packed n elevations per word.

MPKD The block data record.

MPKD(1) gives the latitude and longitude of the block.

MPKD(2) gives the packing information required to decode the data.

MPKD(3) gives the bias to be applied to the data.

MPKD(7) is the first word of the array of elevations.

ROUTINES CALLED

LDDTPO calls subroutine READPRF, ISEARCH, and various Record Manager routines.

CALLED BY

LDDTPO is called by function ELVTPO.

LOCAL VARIABLES

TOPO - Local name for the file containing the topographic data on magnetic tape.

TOPS - Local name for the word-addressable, scratch file to which block of data are written from TOPO.

LATX - The latitude boundaries for the topographic data tape.

LONX - The longitude boundaries for the topographic data tape.

KODE - A check for proper topographic data tape. In the topographic data tape preface, KODE = 1 indicates format of file TOPO is compatible with LDDTPO.

WPRF - A logical flag used to determine if FITs for TOPO and TOPS have been created and the necessary fields intialized.

LDRS - The index for file TOPS, Index consists of latitude and longitude (of southwest corner) for blocks that have been written to file TOPS.

JDRS - An integer array containing usage information for the blocks of data contained in file TOPS.

IX - An integer array used to contain the index records for each latitude partition read from file TOPO.

SUBROUTINE DESCRIPTION

Upon entry the routine first checks in sequence whether the desired block is already in /PKDTPO/, whether the tape reading has been initialized, or whether the desired block is stored in TOPS.

In the initialization process, the preface record is read from the tape, the value of KODE is checked, and the extremes of latitude and longitude are noted. The scratch file TOPS is defined to be a Word Addressable (WA) file with a fixed length record of 24530 characters--the length of the common block /PKDTPO/. In addition, a counter is set to indicate to the routine what latitude data partition currently is being read.

If the record is in /PKDTPO/, the routine immediately returns. If it is in TOPS, it is transferred to /PKDTPO/ and the routine returns. Otherwise, the desired block is checked to see if it lies within the range of the tape, and only then does the routine begin to read the tape. The latitude data partition counter is examined, and if it does not correspond to the desired latitude, the proper number of partitions are skipped, the index record is read, and a second counter is set to indicate what record of the partition can be read next. The index is examined at the desired longitude and, depending on its value, the proper action is taken. If the index is positive the routine skips the proper number of records and finally reads the desired one into the array MPKD. It computes the unpacking

aids using MPKD(2).

Each time a new data block is established in /PKDTPO/, no matter what its status NPKD, the routine will write the entire common block into TOPS. The first ten such records are written in sequential order. After that, one of the previously written records is deleted from the stack and replaced by the present one. The one deleted is chosen to be that record which has not been used (or reused) for the longest period of time.

Only one TOPO tape may be used in any one job. Furthermore, the user should not issue any outside commands that will affect the positioning of the file TOPO. If he does, the synchronization within LDDTPO may be lost.

At present the parity checks are not implemented. The user must rely on such information as he can obtain from the dayfile.

B.2.3.6 PFLTPO

Subroutine PFLTPO extracts a path profile from the TOPO data base. Originally written by George Hufford, this version has been modified for use with the CSPM. The maximum number of points per profile has been increased from 601 to 1251 to achieve higher resolution for long paths.

ARGUMENTS

ALAT - Transmitter latitude in decimal degrees north.

ALON - Transmitter longitude in decimal degrees east.

BLAT - Receiver latitude in decimal degrees north.

BLON - Receiver longitude in decimal degrees east.

XXI - Distance increment between points of the profile in meters to be used as an initial estimate.

IERR - Error flag.

COMMON BLOCKS

PFLTPO uses the common blocks /OPTIONS/ and /PFILE/ described in Tables B-4 and B-7.

ROUTINES CALLED

PFLTPO calls the following routines:

DESIC

ELVTPO

QDESIC

CALLED BY

PFLTPO is called by LOSSMOD.

SUBROUTINE DESCRIPTION

PFLTPO determines the number of profile points to be used from the path length and the initial distance increment XXI. The path length in meters and the bearing from the transmitter to receiver is calculated by DESIC. If this profile is for a map radial, this distance is rounded to the next kilometer. The number of intermediate points on the path at which the elevation is to be extracted from the TOPO base is then calculated by dividing the path length by XXI and rounding up to the next integer value. A maximum of 1251 profile points is allowed. The actual spacing between points is determined by dividing the path length by the number of intervals between profile points. PFLTPO then loops through all the profile points, calling QDESIC to return the latitude and longitude of the intermediate point and ELVTPO to extract the elevation from the TOPO base. These elevations are stored sequentially in array PFL, with the transmitter site elevation stored in PFL(1) and the receiver site elevation in PFL(NP+1).

B.2.3.7 QDESIC

Subroutine QDESIC calculates the latitude and longitude for the end-point of a path given the latitude and longitude of the initial point, the bearing, and the path length. The alternate entry point, DESIC, uses the latitude and longitude of both endpoints of a path to calculate the bearing and path length.

ARGUMENTS

ALAT - Latitude of point 1 in decimal degrees north.

ALON - Longitude of point 1 in decimal degrees east.

BLAT - Latitude of point 2 in decimal degrees north.

BLON - Longitude of point 2 in decimal degrees east.

AZIM - Bearing of path in decimal degrees clockwise from north.

DST - Path length in meters.

ROUTINES CALLED

None.

CALLED BY

QDESIC and DESIC are called by LDDTPO and PFLTPO.

ENTRY POINTS

DESIC is called to calculate path length and bearing given the latitude and longitude of both endpoints of the path.

SUBROUTINE DESCRIPTION

QDESIC and DESIC use the relationships of spherical trigonometry to calculate the requested values.

B.2.3.8 QDLTH

Subroutine QDLTH computes DLTH, the terrain irregularity, for a given path profile. Terrain irregularity is defined as the interdecile range of the deviations of the elevations at points along the profile from the corresponding values on a least squares linear approximation to the profile.

ARGUMENTS

None.

COMMON BLOCKS

QDLTH uses the common blocks /PFILE/ and /EVPARS/ described in Tables B-7 and B-9.

ROUTINES CALLED

QDLTH calls QTILE.

CALLED BY

QDLTH is called by QPARS.

SUBROUTINE DESCRIPTION

QDLTH initially calculates the coefficient for a least-squares linear approximation to the profile elevations. It then calculates the deviation of each point on the profile from the least-squares approximation. QDLTH calls QTILE to partially order this array of deviation values. The

interdecile range then is defined as the difference between the 10th and 90th percentiles of the array of deviations. DLTH is an asymptotic value determined as a function of the distance and the interdecile range.

B.2.3.9 QPARS

Subroutine QPARS calculates the path parameters used by the Longley-Rice routines in the point-to-point mode.

ARGUMENTS

None.

COMMON BLOCKS

QPARS uses the common blocks /PFILE/, /EVPARS/, /PHPARS/, and /SVPARS/ described in Tables B-7, B-9, B-10, and B-11.

ROUTINES CALLED

QPARS calls QDLTH and FFGND.

CALLED BY

QPARS is called by LOSSMOD.

ENTRY POINTS

QPARX is called when an approximation to DLTH is to be calculated instead of calling QDLTH.

SUBROUTINE DESCRIPTION

QPARS calls QDLTH to calculate the terrain irregularity, DLTH. HSYS is the average of the transmitter and receiver site elevations. ENS may be input by the user or calculated from ENO and HSYS. QPARS also calculates the horizon elevation anagles, distances to the horizon, elevations at the horizons, and effective antenna heights. The flag ISO is set to 0 for a line-of-sight path and ≠ 0 otherwise.

B.2.3.10 QRTHETA

Subroutine QRTHETA calculates the latitude and longitude of the point where a radial from the transmitter at bearing AZIM intersects the map boundary.

ARGUMENTS

AZIM - Bearing of the radial in decimal degrees.

ZLAT - Latitude of the intersection point in decimal degrees north.

ZLQN - Longitude of the intersection point in decimal degrees east.

COMMON BLOCKS

QRTHETA uses the common blocks /OPTIONS/ and /LOSSMOD/ described in Tables B-4 and B-5 respectively.

ROUTINES CALLED

None.

CALLED BY

QRTHETA is called by LOSSMOD.

SUBROUTINE DESCRIPTION

QRTHETA uses the relationships of sperical trigonometry to calculate the point where a map radial at bearing AZIM intersects the latitude/longitude boundaries of the map.

B.2.3.11 QTILE

Subroutine QTILE partially reorders the elements of an array so that A(J), J=1, IR are all greater than or equal to all A(J), J=IR, NN. In particular A(IR) will have the same value it would have if the array were completely sorted in descending order.

ARGUMENTS

NN - Number of elements of the array to be ordered.

A - Array to be ordered.

IR - Array elements are to be sorted so that A(J), J=1, IR are all greater than or equal to A(J), J=IR, NN.

COMMON BLOCKS

None.

ROUTINES CALLED

None.

CALLED BY

QTILE is called by QDLTH.

SUBROUTINE DESCRIPTION

QTILE is called to partially sort the elements of array A. Elements are interchanged until the first IR elements are the largest. This routine is used to order values for QDLTH so that it can determine the 10th and 90th quantiles.

B.2.3.12 READPRF

Subroutine READPRF is called to create the FIT (File Information Table) for reading the TOPO tape.

ARGUMENTS

FIT - Array containing the record manager FIT and I/O buffer for reading the TOPO tape.

LFN - Logical file name of the TOPO tape.

MRLW - Maximum record length in words for the TOPO tape.

COMMON BLOCKS

READPRF uses the common block /PREFACE/ described in the documentation for LDDTPO.

ROUTINES CALLED

READPRF calls record manager routines to set fields in the FIT.

CALLED BY

READPRF is called by LDDTPO.

ENTRY POINTS

PRNTPRF is called to print the information contained in the PREFACE record on the TOPO tape.

SUBROUTINE DESCRIPTION

READPRF calls FILESQ to set up a FIT for the sequential tape file TOPO. It opens the file for INPUT and stores the maximum record length in the FIT. It uses a 1065 word buffer beginning at FIT(36). READPRF reads the PREFACE record from the TOPO tape.

B.2.3.13 Longley-Rice Propagation Loss Model Routines

The routines ACRLR, ADHLR, AKNFLR, ALOSLR, DEELR, EIGLER, FHZLR, HOFLR, SCATLR, QLRAP, and QVARLR are also a part of the (2,0) overlay. These routines with XLBLR in the (3,0) overlay comprise the Longley-Rice propagation loss model used in the point-to-point mode by the CSPM. The Longley-Rice model is discussed briefly in Appendix C of this report and documented in the reports by Longley and Rice (1968) and Rice, et al. (1967) to which the reader is referred for additional detail.

B.2.4 (3,0) Overlay Routines

B.2.4.1 OUTPUT

Program OUTPUT is the controlling routine for the (3,0) overlay. It reads both PROFILE and ACR DATA records from the LOSS or RESTRT files. OUTPUT calls PRTAB to produce the requested path profile output. If this is a single path and basic transmission loss (LB) has been requested, OUTPUT calculates and prints the basic transmission loss for the path. For a geographic area, OUTPUT uses the ACR and statistical data read for each radial to calculate basic transmission loss and communication reliability values at each data point along the radial. These values are used by PRLOSS to print the requested tabulated output and are written to file CNTR to be read by CONTOUR to produce the selected contour plots.

COMMON BLOCK

OUTPUT uses the /OPTIONS/, /LOSSMOD/, /LRVAR/, and /LBREL/ common blocks. These are described in Tables B-4, B-5, B-14, and B-16, respectively.

ROUTINES CALLED

OUTPUT calls the following routines:

CONTOUR

HEADER

PLOTF (CALCOMP initialization routine)

PQFF (CALCOMP termination routine)

PRLOSS

PRTAB

QERF

QERFI

XLBLR

SMODE (CALCOMP routine).

CALLED BY

OUTPUT is called by CSPM.

PROGRAM DESCRIPTION

If this is an initial run, the PROFILE and ACR DATA records for OUTPUT to read are on file LOSS. To properly position the LOSS file, OUTPUT rewinds the file and skips the OPTIONS record. If this is a restart run, the PROFILE and ACR DATA records are read from RESTRT. Since INPUT will already have read the OPTIONS record, the RESTRT file does not need to be repositioned. OUTPUT initially calls QERFI to calculate the standard normal deviates for the variability sets used. It also calculates the constants that are added to basic transmission loss values to calculate power density and received signal level. If a geographic area is being analyzed instead of a single path, OUTPUT will print the CSPM Output Data Summary for a geographic area. OUTPUT then reads each record from the LOSS or RESTRT file until it finds an EOF. If the record read is a PROFILE record, PRTAB is called to tabulate or plot the profile data. If the record read is an ACR DATA record and the run is for a single path, OUTPUT calculates and prints the basic transmission loss for the path. For a geographic area, OUTPUT uses the ACR and statistical data for the radial to calculate basic transmission loss and communication reliability values for each point along the radial. If tabulated output has been selected for this radial, PRLOSS is called to print LB, PD, RSL, and REL. If contour plots have been requested, these data are written to file CNTR. When all the records on file CNTR have been read, OUTPUT checks the plot flag to see if contour plots have been requested. If they have, CONTOUR is called to read the CNTR file and produce the CALCOMP plots.

B.2.4.2 CONTOUR

Subroutine CONTOUR produces all of the contour plots.

ARGUMENTS

XLMAX - Array of maximum loss value for each variability set.

XLMIN - Array of minimum loss value for each variability set.

PDC - The constant for computing power density from loss data.

RSLC - The constant for computing received signal level from loss data.

ROUTINES CALLED

PTITLE.

Plotting Routines.

CALLED BY

OUTPUT.

LOCAL VARIABLES

HEIGHT - The height of the page to contain a plot in plotter units.

WIDTH - The width of the page to contain a plot in plotter units.

SIZE - The vertical size of a plotted letter in plotter units.

WL - The width of a letter in plotter units.

TYPE - Array of specified plot types

1 = Basic Transmission Loss

2 = Power Density

3 = Received Signal Level

4 = Reliability

NTYPE - The number of types of plots in TYPE array.

C - Array of levels to be contoured.

NC - Number of levels to be contoured.

XLOSS1 - Array of still active loss data.

XREL1 - Array of still active reliability data.

XLOSS2 - Array of loss data from radial which was just read in.

XREL2 - Array of reliability data from radial which was just read in.

COOR - Linked array of coordinates for contour lines.

P - Array of pointers into COOR list.

NCH - Number of groups of points which form continuous lines in COOR.

SUBROUTINE DESCRIPTION

Subroutine CONTOUR checks the flags for contour plots and produces all specified plots in a single call. PTITLE is called for each plot to calculate the levels to be contoured, and to write a title and contour level key on the plot.

Loss and Reliability data for the plots is read from logical unit 10 one radial at a time. It calculates the endpoints of all possible contour lines between the last two radials before reading in the next one. The endpoints are calculated by linear interpolation between data points. The endpoints are stored as linked lists where each list forms a continuous contour line.

Once all the radials have been read in, the contours are drawn. A mark is put at the transmitter location with a circle of radius 1 km drawn around it. CONTOUR then goes on to the next plot.

B.2.4.3 PRLOSS

Subroutine PRLOSS prints tabulated CSPM evaluation data for selected radial paths. Any combination of basic transmission loss, power density, received signal level, and communication reliability values may be printed for all variability sets.

ARGUMENTS

PDC	Power density constant used to calculate PD in dBm/m^2 from basic transmission loss, PD = PDC - LB.
RSLC	Received signal level constant used to calculate RSL in dBm from basic transmission loss, RSL = RSLC - LB.
XDLTH	Terrain irregularity in meters for this radial.
XENS	Surface refractivity for this radial.
DIST	Path length in meters.

COMMON BLOCKS

PRLOSS uses common block /OPTIONS/ described in Table B-4.

ROUTINES CALLED

None.

CALLED BY

PRLOSS is called by OUTPUT.

SUBROUTINE DESCRIPTION

PRLOSS prints a short summary heading called CSPM Evaluation Data which gives the radial bearing, length in meters, and path parameter information. Next, the column headings for the requested types of output (LB, PD, RSL, REL) are printed. Column headings for each specified variability set are also printed. For each data point along the radial, the requested power density and received signal level values are calculated from LB. Then the values of LB, PD, RSL, and REL for that subpath are tabulated together with the subpath length in kilometers. If the data must be continued on subsequent pages, PRLOSS calls HEADER to title the new pages and prints the appropriate column headings on each.

B.2.4.4 PROFILE

Subroutine PROFILE draws the path profiles.

ARGUMENTS

PFL	An array of profile elevations in meters.
NP	The number of points in PFL array.
D	The length of the path in meters.
THETA	The bearing of the path (if a map radial).
EERC	The effective earth radius for the path.

CALLING ROUTINES

PRTAB calls it for each profile.

ROUTINES CALLED

XAXIS to draw the horizontal axes.

Plotting routines.

LOCAL VARIABLES

ZSF	Vertical scale factor.
ZINIT	Minimum elevation of vertical axis in meters.
DINC	Distance increment along horizontal axis in plotter units.
XINC	Distance increment along horizontal axis in kilometers.
ZAXIS	Height of vertical axis in plotter units.
XLNGTH	Length of horizontal axis in plotter units.

SUBROUTINE DESCRIPTION

PROFILE writes the run title in the upper right-hand corner of the plot and the data and time in the upper left-hand corner. Across the top it writes a title which depends on whether it's a single path or a map radial. It writes the transmitter and receiver (single path only) coordinates in degrees, bearing (map radial only), the path length in kilometers and miles, and the effective earth radius in kilometers. If the size of the earth's bulge for the path is larger than two-thirds of the maximum difference in elevation along the path, then a flat earth is drawn. For a curved earth a parabolic approximation is used. Vertical axes are in both meters and feet. Horizontal axes are in both kilometers and miles.

B.2.4.5 PRTAB

Subroutine PRTAB prints tabulated path profile data for single paths or selected radial paths within a geographic area. It also prints the heading information for plotted profiles and calls PROFILE to produce the CALCOMP plots.

ARGUMENTS

IPLT	Plot or tabulate flag. If IPLT = -1, the heading is printed and PROFILE is called to plot the path profile. If IPLT = 0, the heading is printed and the tabulated path profile data are printed. If IPLT = 1, the heading is printed, the tabulated path profile data are printed, and PROFILE is called to plot the profile.
AZIM	Bearing decimal degrees clockwise from north.
XDLTH	Delta-H (terrain irregularity) in meters for this path.
ENS	Surface refractivity for the path.
HSE	HSE(1) = transmitter effective surface elevation in meters above MSL. HSE(2) = receiver effective surface elevation in meters above MSL.
DL	DL(1) = distance in meters from the transmitter to its horizon.

	DL(2) = distance in meters from the receiver to its horizon.
HL	HL(1) = transmitter horizon elevation in meters.
	HL(2) = receiver horizon elevation in meters.
D	Path length in meters.
XI	Distance increment in meters between profile points.
NP	Number of profile points - not including the receiver location.
PFL	Array containing NP+1 profile elevations in meters.

COMMON BLOCKS

PRTAB uses the /OPTIONS/ common block described in Table B-4.

ROUTINES CALLED

PRTAB calls the following routines:

HEADER.

PROFILE.

CALLED BY

PRTAB is called by OUTPUT.

SUBROUTINE DESCRIPTION

Subroutine PRTAB calls HEADER to title a new page and then checks to see if the profile data to be tabulated are for a single path or a radial path. If it is a single path case, PRTAB prints the CSPM Output Data Summary for a single path. For a radial path, PRTAB prints an abbreviated heading called Topographic Profile Data. Both contain information about the path length and path parameters. The profile elevations and the distance of the point from the transmitter are printed in both English and International units. If more than one page is required to tabulate all the profile elevations, PRTAB calls HEADER to title the page and also to print the column headings on each continuation page. When all data have been printed, the PRO flag is checked to see if a plotted profile has been requested. If so, PROFILE is called to create the CALCOMP plot.

B.2.4.6 PTITLE

Subroutine PTITLE writes the title and contour level key on the contour plots. It also computes the contour levels.

ARGUMENTS

XLMAX	The maximum loss values for each variability set.
XLMIN	The minimum loss values for each variability set.
PDC	The constant for computing power density from loss data.
RSLC	The constant for computing received signal level from loss data.
TYPE	Integer array containing the contour plots which were requested: 1 = Basic Transmission Loss 2 = Power Density 3 = Received Signal Level 4 = Communication Reliability.
T	Index to the TYPE array (integer).
V	Which variability set: 1 = V1 2 = V2 3 = V3.
HEIGHT	Height of page containing the plot.
WIDTH	Width of page containing the plot.
SIZE	Vertical size of plotted character.
WL	Width of a plotted character.
LETTER	Array of letters for contour level key.
C	Array of contour levels for CONTOUR.
NC	Number of contour levels.
YC2	Y-coordinate of upper edge of contour map.

COMMON BLOCKS

PTITLE uses the common block /OPTIONS/ described in Table B-4.

ROUTINES CALLED

Plotting routines.

CALLING ROUTINES

CONTOUR.

LOCAL VARIABLES

CONTR Array of contour levels for the key.

SUBROUTINE DESCRIPTION

PTITLE writes the run title in the upper right-hand corner of the plot and the date and time in the upper left-hand corner. Across the top it writes the type of contours being plotted and the variability set which was used to compute the data for the plot. After determining the levels to be contoured, PTITLE writes a key at the bottom of the plot. For the Basic Transmission Loss, Power Density, and Received Signal Level contours the levels are computed so that they will be evenly spaced multiples of 5 with a maximum of ten levels. For these three types of plots CONTOUR does the plotting from basic transmission loss data so PTITLE sends it the corresponding contour levels. The reliability contour levels are specified by the user. PTITLE removes any duplicates and sorts them into descending order.

B.2.4.7 QERF

Function QERF converts a standard normal deviate to a probability value.

ARGUMENTS

X Standard normal deviate for time availability (ZT), location variability (ZL), or confidence (ZC).

ROUTINES CALLED

None.

CALLED BY

QERF is called by OUTPUT.

FUNCTION DESCRIPTION

QERF uses a Chebyshev approximation to the standard normal complementary probability due to C. Hastings, Jr., in "Approximations for Digital Computers," Princeton University Press, 1955. It has a maximum error of 7.5 E-8. To avoid underflow QERF is truncated at $|X| = 10$. This is the

"q error function" returning the probability that the value X is exceeded under a standard normal distribution.

B.2.4.8 QERFI

Function QERFI converts a probability value to a standard normal deviate. It is the inverse of QERF.

ARGUMENTS

Q - Probability value for time availability (QT), location variability (QL), or confidence (QC).

ROUTINES CALLED

None.

CALLED BY

QERFI is called by OUTPUT.

FUNCTION DESCRIPTION

QERFI returns the standard normal deviate as a function of the complementary probability truncated at 0.00001 and 0.99999. It uses the approximation due to C. Hastings, Jr., in "Approximations for Digital Computers," Princeton University Press, 1955, and has a maximum error of 4.5 E-4.

B.2.4.9 XAXIS

Subroutine XAXIS draws the two horizontal axes on the path profile. The axes are curved according to the effective earth radius.

ARGUMENTS

Z	The Z-coordinate of the starting point of the axis. The X-coordinate is an implied zero.
LABEL	A character string title for the axis.
NL	The number of characters in the title if: NL>0 - title will be written above the axis, NL<0 - title will be written below the axis.
AXLEN	The length of the axis.
AXINC	The distance between tick marks.

DINC The increment for the data values to be written by the tick marks. The first value is always zero.

F A constant for computing the amount of curvature.

COMMON BLOCKS

None.

ROUTINES CALLED

Plotting routines.

CALLING ROUTINES

PROFILE.

SUBROUTINE DESCRIPTION

XAXIS draws a curved axis according to the factor "F". "F" is computed for a parabolic approximation of the curvature of the earth using its effective radius. The axis and tick marks are labeled as specified by the parameters.

B.2.4.10 XLBLR

Function XLBLR calculates basic transmission loss (LB) from the ACR values input in the common block /LRVAR/. The value returned is the loss that is not exceeded with confidence QC in at least QL of the locations for at least QT of the time.

ARGUMENTS

ZT - The standard normal deviate for time availability (QT).

ZL - The standard normal deviate for location variability (QL).

ZC - The standard normal deviate for confidence (QC).

YT - Variability in attenuation due to long-term fading. This value is returned.

YL - Variability in attenuation due to random path selection. This value is returned.

YC - Variability in attenuation due to prediction confidence. This value is returned.

COMMON BLOCKS

XLBLR uses common block /LRVAR/ defined in Table B-14.

ROUTINES CALLED

None.

CALLED BY

XLBLR is called by OUTPUT.

FUNCTION DESCRIPTION

XLBLR calculates the basic transmission loss for the path as the sum of the free-space loss and the calculated reference modified by the variability due to long-term fading, random path selection, and prediction confidence.

B.3 CSPM Installation Instructions for a SCOPE 3.4 System

The CSPM source is being delivered as an UPDATE PL on a 7-track, 800 bpi density, unlabeled, SI format tape. The following control cards should be used to create and execute the CSPM overlays.

```
CSPM,T77,MT1.
REQUEST(NEWPL,*PF)
REQUEST(CSPM,*PF)
REQUEST,TAPE,VSN=CSPM,HY,MT.
UPDATE(P=TAPE,F,N,*=/)
CATALOG(NEWPL,CSPMPL,ID=XXX)
FTN(I,R=3)
ATTACH(CLIB,ID=XXX)             Library of CALCOMP, routines plotter
MAP(P)
RFL,100000.
LDSET(PRESET=NGINDEF)
LDSET(LIB=CLIB/FORTRAN/SYSIO)
LDSET,USE=$CLSV.WA$/$GET.FIT$/$REW.SQ$.
LDSET,USE=$OPEN.WA$/$PUT.WA$/$GET.WA$/$CLSF.WA$.
LDSET,USE=$GET.W$/$GET.R$/$GET.D$.
LDSET,USEP=$INCOM=$/SYSTEM/SYSTEMC.
LOAD(LGO)
NOGO.
CATALOG(CSPM,ID=XXX)
RETURN(TAPE)
```

```
LABEL(TOPO,MT,HY,VSN=ZZZZ)   Topographic data tape
CSPM.
7/8/9
CSPM TEST CASE
XMTRCOOR=(31,29,00,N/110,20,00,W),XMTRLOC=HUACHUCA,
MAP=(31,27,00,N/31,34,00,N/110,26,30,W/110,17,30,W), TABL=16,PLOT=0
FREQ=394.675,POL=V,HG1=20,HG2=6FT,LB,PD,RSL,REL,PTAB=16
V1=(.9,.9,.9),V2=(.9,.9,.5),V3=(.9,.5,.5)
RSLTH=-85.5,RQ=(.99,.90,.50,.10),G2=10
GND=POOR,PWR=100W,G1=15
6/7/8/9
```

APPENDIX C. LONGLEY-RICE PROPAGATION LOSS MODEL

C.1 General Summary

The Longley-Rice propagation loss model is the best general purpose model available at the Institute for Telecommunication Sciences for predicting long-term (hourly) median radio transmission loss at VHF and higher frequencies over irregular terrain. The method is based on well-established propagation theory which has been documented in considerable detail (see Rice et al., 1967; Longley and Rice, 1968; and Longley, 1976). The model has been tested against a large number of propagation measurements and used extensively to provide information about area-wide situations employing line-of-sight, diffraction, and troposcatter types of communication systems. The model frequently is used to analyze broadcast and mobile system applications where only moderate detail is known about the propagation path. For such analyses, statistical descriptors of terrain characteristics (i.e., terrain irregularity, surface refractivity, etc.) are used. The CSPM, however, uses the Longley-Rice propagation loss model in the point-to-point mode. In this mode, a particular propagation path may be considered for which a path terrain profile is generated and used to provide the details of terrain characteristics along the propagation path. That is, the path is determined to be line-of-sight, diffraction, or troposcatter; and appropriate influences upon the radio signals are supplied mathematically.

The prediction method has been developed for operation on a high speed, digital computer, whereby predictions have been tested against data for wide ranges of frequency, antenna height and distance, and for all types of terrain from very smooth plains to extremely rugged mountains. The data base includes more than 500 long-term recordings throughout the world in the frequency range 40 to 10,000 MHz, and several thousand mobile recordings in the United States at frequencies from 20 to 1,000 MHz. Some experience has shown that the model will overestimate the loss for good line-of-sight paths.

The "heart" of the propagation loss model is the calculation of median values of reference attenuation relative to free-space loss as a function of distance. This modification to the free-space loss takes into consideration whether the path is line-of-sight, diffraction, or tropospheric scatter.

For radio line-of-sight paths, the calculated reference attenuation factor is based on two-ray theory and an extropolated value of diffraction attenuation. For transhorizon paths, the reference value is either diffraction attenuation or forward scatter attenuation, whichever is smaller. Further considerations due to the influences of season and climate upon propagation loss also are included.

Without defending derivation of the expression, which is contained in the references cited above, an expression can be written for basic transmission loss, with quantities expressed in decibels, as

$$L_b = L_{fs} + A_{cr} - V \tag{C-1}$$

where:

L_{fs} is the calculated free-space loss,

A_{cr} is the calculated reference attenuation factor relative to free-space loss and depends on whether the path is line-of-sight, diffraction, or tropospheric scatter, and

V is an empirically determined adjustment to the calculated reference attenuation factor to provide a median attenuation factor, denoted A(0.5), for specific seasons and climates.

Median basic transmission loss can be expressed, then, as

$$L_b(0.5) = L_{fs} + A_{cr} - V(0.5) \tag{C-2}$$

$$= L_{fs} + A(0.5)$$

where the (0.5) denotes median conditions. Discussion on the time, location, and prediction confidence variabilities, to allow calculations of basic transmission loss for other than median conditions, is contained in the next section of this appendix. Other terms in (C-1) will be discussed briefly in the remainder of this section.

The general expression for free-space propagation loss is

$$L_{fs} = 10 \log_{10} ((4\pi fd)/c)^2, \tag{C-3}$$

where d is the distance (path length), f is the carrier frequency of the radiated signal, and c is the propagation velocity in free space. When frequency is expressed in megahertz and distance is expressed in kilometers, the free-space loss expression becomes

$$L_{fs} = 32.45 + 20 \log_{10}(fd) \quad , \tag{C-4}$$

As indicated earlier, the reference attenuation factor depends upon whether the path is line-of-sight, diffraction, or tropospheric scatter. The graph in Figure C-1 shows how A_{cr} varies with distance.

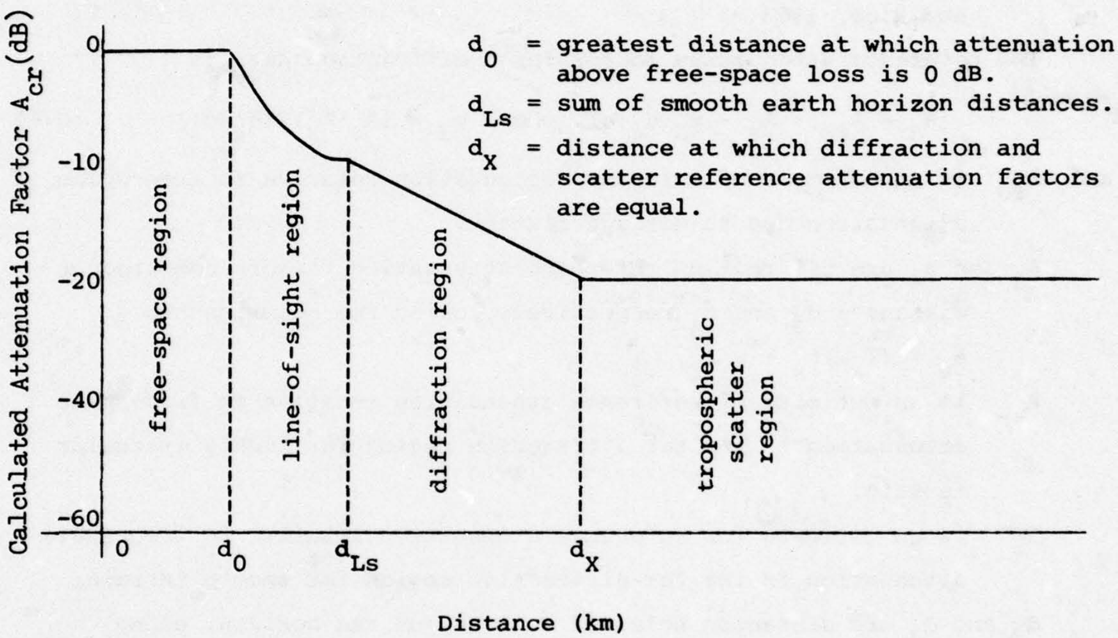

Figure C-1. Calculated attenuation factor A_{cr} versus path length for line-of-sight, diffraction, and tropospheric scatter regions.

In the free-space region A_{cr} is 0 since there is no attenuation above free-space loss. For a line-of-sight path, where a weighted average of two-ray optics theory and diffraction theory is applied, the reference attenuation is calculated as

$$A_{los} = A_0 + k_1(d-d_0) + k_2 \log_{10}(d/d_0) \tag{C-5}$$

where

A_0 is a weighted average attenuation above free-space loss computed at a distance d_0 using techniques defined by Longley and Rice, 1968;

d_0 is a distance selected to approximate the greatest distance at which the attenuation above free-space loss is 0 dB, and

k_1 and k_2 are constants determined by techniques defined by Longley and Rice, 1968.

The reference attenuation factor for a diffraction path is

$$A_d = A_{fo} + A_4 - m_d(d_4-d), \text{ where } m_d = (A_4-A_3)/(d_4-d_3) \qquad \text{(C-6)}$$

and A_{fo} is an estimate of reference attenuation relative to free-space attenuation due to surface clutter,

A_3 and A_4 are diffraction reference attenuation factors computed at distances d_3 and d_4 respectively, using the relationship $A_d = (1-w)A_k + w\,A_r$,

A_k is an estimate of reference attenuation relative to free-space attenuation in the far diffraction region for highly irregular terrain,

A_r is an estimate for reference attenuation relative to free-space attenuation in the far diffraction region for smooth terrain,

d_3 and d_4 are distances selected well beyond the horizon, using techniques defined by Longley and Rice, 1968, at which diffraction reference attenuation factors are calculated, and

w is a weighting factor empirically determined by techniques defined by Longley and Rice, 1968.

Reference attenuation relative to free-space attenuation for a forward scatter path is

$$A_s = A_5 - m_s d_5 + m_s d, \text{ where } m_s = (A_6-A_5)/(d_6-d_5) \qquad \text{(C-7)}$$

and

A_5 and A_6 are factors of scatter reference attenuation above free-space loss computed at distances d_5 and d_6 respectively, using estimating techniques defined by Longley-rice, 1968; and

d_5 and d_6 are distances selected to be 200 km and 400 km greater respectively, than the sum of the distances from each antenna to its respective horizon.

For transhorizon paths, the reference attenuation relative to free-space attenuation is defined to be the diffraction reference attenuation factor for $d_{Ls} \leq d \leq d_x$ and the tropospheric scatter reference attenuation factor for $d \leq d_x$ where d_{Ls} is the sum of the smooth earth horizon distances and d_x is the distance at which diffraction and scatter reference attenuation factors are equal.

The specification of atmospheric refractivity is allowed as either the surface refractivity, N_s, or the surface refractivity referenced to mean sea level, N_0. Values throughout the world of surface refractivity referenced to mean sea level (N_0) may be found in the CCIR (1974) report or the monograph by Bean et al. (1960). However, the propagation loss model requires the surface refractivity (N_s). When surface refractivity referenced to mean sea level is specified, it is converted to surface refractivity as shown by (D-3) in Appendix D. A commonly-used value for surface refractivity is N_s = 301 N-units, which corresponds to an effective 4/3 earth radius.

C.2 Discussion of Statistical Variabilities

The median basic transmission loss, a function of distance, described in the preceding section is combined (by addition processes when values are expressed in decibels) with still other parameter values which account for the variabilities in transmission loss due to long-term fading (time availability), path-to-path variations, and estimating confidence. These operations provide predicted basic transmission loss which will not be exceeded for at least the specified time (q_T) over at least the required fraction of paths (q_L) with stated confidence (Q). The loss variability parameters commonly are referred to as Y-parameters with the time availability influence denoted by Y_T, the location variability influence for specified time availability conditions denoted by Y_L, and the estimating confidence influence for specified time availability and location variability conditions denoted by Y_C.

The Y-parameters express attenuation variability in decibels and are considered to be approximately normally distributed with zero means and variances of σ_T^2, σ_L^2, and σ_C^2 respectively. They each are written in terms

of the standard $Z_0(q)$ where $0 \leq q \leq 1$ and their standard deviations σ_T, σ_L, and σ_C. The standard normal deviate is expressed in terms of the error function exf(x) and its inverse $\mathrm{erf}^{-1}(x)$ as

$$Z_0(q) = \sqrt{2}\ \mathrm{erf}^{-1}(2q-1) \tag{C-8a}$$

and

$$q = 0.5 + 0.5\ \mathrm{erf}(Z_0/\sqrt{2}) \quad . \tag{C-8b}$$

The standard deviation for each variability has been determined empirically from measured data cited in the report references mentioned earlier in this appendix.

The long-term time variability about the median attenuation is approximately normal and calculated as follows:

$$\text{If}\quad Z_0(q_T) < 0,\quad Y_T = \sigma_{TM}\, Z_0(q_T) \tag{C-9}$$

$$\text{If}\quad Z_0(q_T) = 0,\quad Y_T = 0$$

$$\text{If}\quad Z_0(q_T) > 0 \quad \text{and} \quad Z_0(q_T) > ZD \quad ,$$

$$Y_T = \sigma_{TD}\, Z_0(q_T0 + YD$$

$$\text{If}\quad Z_0(q_T) > 0 \quad \text{and} \quad Z_0(q_T) \leq ZD \quad ,$$

$$Y_T = \sigma_{TP}\, Z_0(q_T)$$

where q_T is the fraction of time when attenuation on the average will not exceed $L_b(1.0) - Y_T$;

σ_{TM} is the standard deviation for the minus range;

σ_{TD} is the standard deviation for the ducting range;

σ_{TP} is the standard deviation for the plus range;

ZD is the standard normal deviate of predicted attenuation for small time variabilities, such as are associated with ducting phenomenon; and

YD is the ducting range breakpoint, ZD · SGTP.

Note that the empirically determined values of σ_{TM}, σ_{TD}, and σ_{TP} are not constant for all climates and effective path lengths. Neither are the variabilities for $q_T < 0.5$ symmetrical with those for $q_T > 0.5$.

Path-to-path variability in attenuation for given time availability is expressed by

$$Y_L = Y(q_T, q_L) = \sigma_L \; Z_0(q_L) \qquad \text{(C-10)}$$

where q_L is the fraction of paths for which attenuation will not exceed the value calculated by $L_b(0.5) - Y_T - Y_L$. The standard deviation σ_L has been determined empirically to be a function of terrain irregularity and frequency and is calculated by

$$\sigma_L = \frac{10\left(1-.8\ e^{-D/50000}\right)\left(\frac{\lambda}{\Delta h}\right)}{13 + \left(1-.8\ e^{-D/50000}\right)\left(\frac{\lambda}{\Delta h}\right)} \qquad \text{(C-11)}$$

where

- λ is the wavelength in meters of the attenuated radio frequency signal;
- D is the path length in meters; and
- Δh is the interdecile range of terrain elevations in meters along the path.

Variability due to prediction confidence for specified conditions of time availability and location variability is determined from the relationship

$$Y_C = \sigma_C^2 + \frac{Y_T^2}{7.8 + \left(Z_0(Q)\right)^2} + \frac{Y_L^2}{24 + \left(Z_0(Q)\right)^2} \qquad \text{(C-12)}$$

where $0 < Q < 1$ is the value for prediction confidence and σ_C is the standard deviation of the normal distribution of the measured data for the given q_T and q_L. The value of σ_C is calculated by

$$\sigma_C = 3e^{\frac{-d_e}{100}} + 5 \qquad \text{(C-13)}$$

where d_e is an effective distance in kilometers calculated as a function of the actual great circle path length, the smooth-earth horizon distances, and the difference in smooth-earth horizon distances at which diffraction and scatter attenuation factors are equal.

The prediction confidence, Q, is then the fraction of measured data points for which attenuation will not exceed the value given by $L_b(0.5) - Y_T - Y_L - Y_C$.

C.3 References

Bean, B. R., J. D. Horn, and A. M. Ozanich, Jr. (1960), Climatic charts and data of the radio refractive index for the United States and the world, NBS Monograph No. 22.

CCIR (1974)*, Radiometeorological data, Report 563, Vol V, XIIIth Plenary Assembly, Geneva.

Longley, A. G. (1976), Location variability of transmission loss -- land mobile and broaccast systems, OT Report 76-87. (NTIS Access No. PB 254 472).

Longley, A. G., and P. L. Rice (1968), Prediction of tropospheric radio transmission loss over irregular terrain, a computer method - 1968, ESSA Tech. Rept. ERL 79-ITS 67. (NTIS Access No. 676-874).

Rice, P. L., A. G. Longley, K. A. Norton, and A. P. Barsis (1967), Transmission loss predictions for tropospheric communication circuits (revised), NBS Tech. Note 101, (NTIS Access No. 687 820 and 687 821).

*Published by the International Telecommunication Union, Geneva, Switzerland.

APPENDIX D. DESCRIPTION OF THE PATH PROFILE CAPABILITY

The capability is required within the CSPM to generate propagation path profiles and extract from them the path parameter data needed as input to the Longley-Rice propagation loss model operating in the point-to-point mode. If desired, the path profile can be obtained as an output from the CSPM for either a single geodesic or selected radial paths extending (at uniform bearing angle increments) from a common origin into the geographical area of interest.

The propagation path is defined in one of two ways. A single geodesic path is defined by specifying the geographical coordinates of the path endpoints; many radial paths are defined by specifying the coordinates of the origin and the latitudes and longitudes to form a geographic "box" containing the origin. (See Appendix F for discussion on selection of radial paths.) In this second method, the CSPM uses the required number of radial paths to compute the bearing angle increment between radial paths. For each radial path, the model also determines the intersection of the radial path with the geographical area boundaries. Endpoints for each radial path then are known, analogous to the input data required for the single path.

Output path profile data for selected radial paths may be obtained by specifying the number (which must be a power of two) of radial paths for which data are desired. The radial paths are selected with uniform bearing angle separation depending upon the number of paths, i.e., four paths provide 90° separation, eight paths provide 45° separation, etc.

Knowing the path endpoints, the CSPM accesses the digitized terrain data file to obtain terrain elevation data at uniform distance intervals along the path. In general, the points along the path at which elevations are required will not coincide (geographically) with the points at which elevation data are stored in the terrain data file. Note that these data are recorded at geographic locations spaced by 30" in latitude and 30" in longitude. This means the data points are separated by distances ranging from about 926 m down to about 583 m, depending upon latitude. (See Appendix E for further details of the topographic data file.) Data at four coordinate locations which define the 30" by 30" "box" containing the coordinate point of interest on the propagation path are retrieved from the terrain file.

A standard bilinear interpolation is performed to estimate terrain elevation at the coordinate point on the path profile.

Path profile point intervals along the radial paths are 250 m, since a variable distance interval would provide considerable difficulty when the path profile data were used to calculate basic transmission loss data at 1 km intervals for the plotted output options of basic transmission loss, power density, received signal level, and communication reliability. The fixed interval does mean that, in general, a data point will not occur at the intersection of the radial path and the area boundary. This situation is overcome by generating the radial path profile to a distance corresponding with the next integer number of kilometers beyond the intersection. The output plots of contoured data simply are restricted to the area within the defined boundaries. A further question might arise about profile data generated at 250 m intervals when the topographic data are separated by intervals ranging from about 583 m to about 926 m. It is evident that the topographic data are used redundantly when generating the path elevation data. Since, in general, every elevation on the path profile is an interpolated value however, it is considered that some smoothing of the path profile achieved through redundant use of the basic terrain data is desirable. Intervals along a geodesic are approximately 250 m for paths less than 312 km in length. For paths greater than 312 km in length, interval distance along the geodesic is determined by dividing the total path length into an integer number of uniform intervals with the restriction that the total number of points along the path must not exceed 1251.

The parameter values required by the Longley-Rice model in the point-to-point mode include:

- Elevation of and distance to the horizon "seen" by each antenna from its path endpoint,
- Terrain irregularity for the path,
- Effective surface heights of terrain in the foreground of each antenna,
- Atmospheric refractivity near the surface of the earth (frequently termed surface refractivity),
- The effective earth's radius considering the surface refractivity for the radial being considered.

These parameters are computed for each path (each point in the area linked with the origin constitutes a path, therefore many paths can occur for a single radial) as part of the path profile and parameter generating capability of the CSPM. The path parameter data are used directly by the Longley-Rice model with no provision for the data being output from the CSPM.

The horizon "seen" by each antenna is determined first by calculating the elevation angle between the transmitting antenna and receiving antenna. Defining the elevation angle to be θ, we have

$$\theta_1 = -\theta_2 \quad , \tag{D-1}$$

where the subscripts 1 and 2 denote the transmitter and receiver respectively. To determine the horizon for the transmitting antenna, the next step is to calculate the elevation angle for each successive point, beginning at the first point beyond the transmitter, along the path profile. If each calculation of elevation angle produces a value less than θ_1, the path is line-of-sight. When elevation angles larger than θ_1 are encountered, the point corresponding to the largest value for the elevation angle is defined to be the horizon. The elevation associated with that point, of course, is the horizon elevation, and the great circle distance between the point and the transmitting antenna location is the distance to the horizon. Working from the receiving antenna location and following the same steps, the horizon, horizon elevation, and distance to the horizon for the receiving antenna are determined.

The terrain irregularity Δh (expressed in meters) is computed once for each entire radial path as the interdecile range of terrain elevations at each point along the path. Terrain irregularity for the subpaths of a radial path is computed using the relationship

$$\Delta h(d) = \Delta h \quad [1 - 0.8 \exp(-0.02d)] \quad , \tag{D-2}$$

where $\Delta h(d)$ is the terrain irregularity in meters for the subpath and d is the subpath length in kilometers.

The effective surface height for terrain in the foreground of each antenna must be provided to the propagation loss model. To do so, the path is divided into segments when transhorizon propagation will occur. Transmitting antenna location to the horizon for that antenna is a path

segment, and receiving antenna location to the horizon for the receiving antenna is another segment. The entire path is considered for line-of-sight conditions. The effective terrain elevation for each segment or the entire path, if appropriate, is calculated as the average elevation for the middle 80% of the path segment or entire path.

A CSPM user may have measurements of the minimum monthly mean surface refractivity, denoted by N_s, for the propagation paths he wishes to study. On the other hand, he may need to rely on use of maps showing the parameter minimum monthly surface refractivity referenced to mean sea level, denoted by N_0, and sometimes termed "reduced surface refractivity." A specification of surface refractivity referenced to mean sea level is converted to surface refractivity by the relationship

$$N_s = N_0 \exp(-0.1057\ h_s), \qquad \text{(D-3)}$$

where h_s is path elevation in kilometers above mean sea level and is computed in the CSPM as the average value for terrain elevations at the transmitting and receiving antenna locations (the path endpoints). The surface refractivity N_s is used to compute an effective earth's radius which allows for regional differences in average atmospheric conditions. The effective earth's radius in kilometers is defined as

$$a = 6370\ [1-0.04665 \exp(0.005577\ N_s)]^{-1} \qquad \text{(D-4)}$$

where the actual earth's radius is taken to be 6370 km.

APPENDIX E. DISCUSSION OF THE TOPOGRAPHIC DATA BASE

The topographic data base, maintained on magnetic tape, contains digitized terrain elevations for the geographical area bounded by 23^{o}N to 51^{o}N latitude and 60^{o}W to 130^{o}W longitude--the continental United States (CONUS) essentially. (Data for a portion of western Europe are expected to be added to the data base in the near future.) The data base provides terrain elevation above mean sea level at every 30" of latitude and 30" of longitude. The data originally were read from 1/250,000 scale maps developed by the Defense Mapping Agency (DMA), then adapted by the Electromagnetic Compatibility Analysis Center (ECAC) for automatic processing. The ECAC data have been reorganized slightly to fit better the constraints of the CDC 6000 series computer.

The basic unit of data is a "block" covering an area 1^{o} by 1^{o} with corners at integer values of latitude and longitude. It is referenced by its southwest corner. Within it, the data can best be pictured as arranged in a two-dimensional array with each index ranging from 0 to 120. If Z represents such an array, then Z(IY,IX) is the ground elevation at latitude LAT + IY/120, longitude LON + IX/120, where LAT, LON, are the coordinates of the southwest corner. Coordinates are expressed in degrees and decimal parts of a degree, and latitudes are expressed as negative in the southern hemisphere. Longitudes west of the reference meridian also are negative. Note that within CONUS, only positive latitudes and negative longitudes are encountered.

The array size for one block is 121 by 121 with a total of 14,641 elements. The data for each element are packed into 60-bit words according to a format that produces variable length data records. The elevations are expressed as coded integer multiples of 20 ft (6.1 m). The minimum elevation value within each data block is decreased by 20 ft (6.1 m), and that value becomes a biased reference elevation for that block. The biased reference elevation is subtracted from each elevation datum within the block, and that elevation difference then is expressed as a positive integer multiple of 20 ft (6.1 m). (The zero value is used to indicate missing data. Next, it is determined whether 2, 3, 4, 5, 6, 7, 8, 10, or 12 bits are required to represent the largest of these elevation differences. Finally, the reduced data are packed consecutively from left to right in

words 30, 20, 15, 12, 10, 8, 7, or 6 elements per word, respectively. (In the case of 8- or 7-bit elements, the four low order bits of each word are unused and set to zero for that reason.) The topographic data tape organization and file structure are shown in Figure E-1. Figure E-2 shows how the data tape organization relates to the geographical area.

A 2-bit element allows a total elevation difference range of only 40 ft (12.2 m). However, if each coded elevation difference integer within a data block could be expressed in this way, only 489 words would be required for the coded and packed elevation difference data. At the other extreme, if the elevation difference were such that the coded integers required 12-bits per datum, such a code would allow an elevation difference of 81,880 ft (24,960 m) and 2929 words would be required to express the coded and packed elevation difference data within the block. A 10-bit element will allow an elevation difference of 20,440 ft (6230 m) which should be sufficient for any data block within the CONUS. When 10-bits per datum are used, 2441 words are required for the data of that block.

Consider an example of decoded terrain elevation where, for a particular block, the minimum elevation is 2360 ft (719.3 m), the maximum elevation is 8740 ft (2664 m), and the elevation difference code is 247. (One might note that 10 bits per datum would be required to code the elevation difference data.) The biased reference elevation would be 2340 ft (713.2 m) for the block. Elevation at the point would be 247 x 20 + 2340 = 7280 ft (2219 m).

The alphanumeric descriptor contained in word six of the coded elevation difference record (illustrated in Figure E-1) nearly always will show a letter "A" which indicates the data source to be the DMA or its predecessor agency, the Army Map Service.

File Structure

Partition 1	Data for 23°N latitude
Partition 2	Data for 24°N latitude
.	.
.	.
.	.
Partition 28	Data for 50°N latitude

Partition Structure

Record 1	Latitude and index to data blocks.
Record 2	Coded elevation differences for block 70 (see Figure F-2).
Record 3	Coded elevation differences for block 69 (see Figure F-2).
.	.
.	.
.	.
Record 71	Coded elevation differences for block 1 (see Figure F-2).

(Fewer records will be used when data for a block are missing or the block is ocean.)

Index Record Structure

Word 1	Integer value of latitude for that partition.
Word 2	*Index for block 70.
Word 3	*Index for block 69.
.	
.	
.	
Word 71	*Index for block 1.

*Index value is zero if data are missing for the block. Index value is -1 if block is ocean. A positive integer declares the number of the record containing data for that block.

Figure E-1. Organization of topographic data tape.

Coded Elevation Differences Record Structure

Word 1	Latitude and Longitude of SW corner of the block. Bits 30-59: Latitude (North = +) Bits 0-29: Longitude (East = +)
Word 2	Bits 30-59: Number of missing data points Bits 12-29: Mask Bits 6-11: Number of bits per datum Bits 0-5: Number of data points per word
Word 3	Integer value of biased reference elevation in feet.
Word 4	Integer value of minimum elevation in feet.
Word 5	Integer value of maximum elevation in feet.
Word 6	Alphanumeric descriptor of data source.
Word 7	Packed and coded elevation differences, 6 to 30 points per word, ordered south to north and west to east starting in the SW corner of the block.
. . .	
. . .	
. . .	
(Sufficient words for 14,641 points)	

Figure E-1. Continued

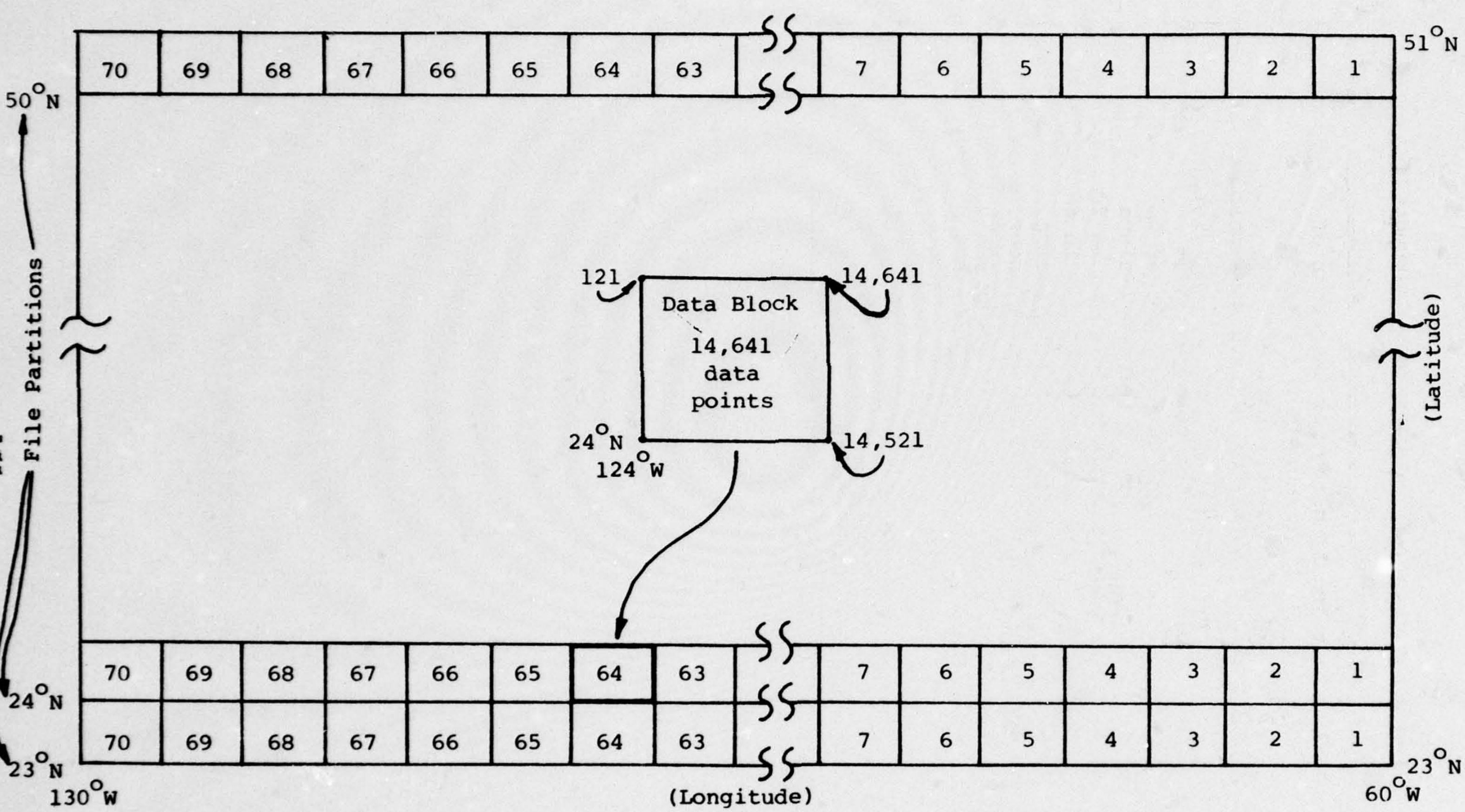

Figure E-2. Illustrated relationships between geographical area and data tape organization for CONUS.

APPENDIX F. DISCUSSION OF OUTPUT DATA AND CONTOURING METHODOLOGY

The variety of calculated output data (basic transmission loss, power density, received signal level, and communication reliability) provided by the CSPM allow the CSPM to be applied to a communication system problem at nearly any stage of the development cycle for the system. For example, basic transmission loss can be calculated when only operating frequency, antenna heights, and polarization are known. When the transmitter output power and transmitting antenna gain are known, the model can provide power density. Additional detail about the system and its application, such as the gain and height of each antenna, polarization, and the transmitter output power, will allow calculations of received signal level. Finally, knowledge of or an assumption about received signal level threshold for satisfactory performance allows an output termed "communication reliability" which provides an overall estimate of satisfactory performance as a function of given time availability and path difference conditions.

From Appendix C, we know the basic transmission loss that is not exceeded a fraction q_T of the time at a fraction q_L of the locations with a prediction confidence Q is

$$L_b(q_T, q_L, Q) = L_{fs} + A_{cr} - V - Y_T - Y_L - Y_C, \qquad \text{(F-1)}$$

where L_{fs} is the calculated free space loss,

A_{cr} is the calculated attenuation factor relative to free-space attenuation,

V is an empirically determined adjustment factor to the reference attenuation factor for specific seasons and climates, and

Y_T, Y_L, and Y_C are the attenuation variabilities imposed upon median basic transmission loss to account for long-term fading effects, random path differences, and prediction confidence, respectively.

It will be useful later in this appendix to recognize that

$$L_{b0} = L_{fs} + A_{cr} - V = L_b(.5, .5, .5) \qquad \text{(F-2)}$$

expresses the median basic transmission loss.

The power per unit area incident upon a surface at a distance R from the transmitting antenna, termed power density, is

$$P_d = P_t \, g/(4\pi R^2) \qquad \text{(F-3)}$$

where P_d is the power density in W/m^2,

P_t is the transmitter output power in watts,

g is the gain of the transmitting antenna ($g=1$ for isotropic radiator), and

R is the distance from the transmitting antenna in meters.

In the CSPM, it is convenient to consider relative values of power density, expressed as decibels relative to a milliwatt per square meter (dBm/m^2), and to use the statistical power density values. The frequency dependence of basic transmission loss must be removed from the value when following such a scheme. The expression for power density in decibels relative to a milliwatt per square meter then can be written as

$$P_d = 20 \log_{10} f + P_T + G_1 - 38.55 - L_b(q_T, q_L, Q), \qquad \text{(F-4)}$$

where f is the carrier frequency in megahertz,

P_T is the transmitter output power in decibels relative to a milliwatt, and

G_1 is the gain of the transmitting antenna in decibels relative to an isotropic antenna (dBi).

The received signal level, RSL, expresses the power delivered by a receiving antenna to the input of its receiver. This quantity takes into consideration the statistical variations in signal attenuation and is calculated as

$$RSL(q_T, q_L Q) = P_T + G_1 + G_2 - L_{pg} - L_b(q_T, q_L, Q), \qquad \text{(F-5)}$$

where P_T and G_1 are as defined for (F-4),

G_2 is the gain of the receiving antenna in decibels relative to an isotropic antenna (dBi), and

L_{pg} is the antenna aperture-to-medium coupling loss in decibels.

$$L_{pg} \begin{cases} = 0 \text{ dB, for } G_1 + G_2 \le 25 \text{ dBi.} \\ = 1 \text{ dB, for } 25 < G_1 + G_2 \le 50 \text{ dBi.} \\ = 0.07 \exp 0.055(G_1+G_2) \text{ dB, for } 50 < G_1 + G_2 \le 100 \text{ dBi.} \end{cases}$$

Since (F-1) expresses the basic transmission loss that is not exceeded, as a function of q_T, q_L, and Q, (F-5) is an expression of the received signal level that is exceeded q_T fraction of the time at q_L fraction of the locations with prediction confidence Q.

One can define satisfactory system performance to be provided when

$$RSL(q_T,q_L,Q) > RSL_{TH} \quad \text{or} \quad RSL(q_T,q_L,Q) - RSL_{TH} > 0, \qquad \text{(F-6)}$$

where RSL_{TH} is a received signal level threshold for satisfactory performance of the system being considered. Subtracting RSL_{TH} from each side of (F-5) and substituting (F-1) and (F-3),

$$RSL(q_T,q_L,Q) - RSL_{TH} = P_T + G_1 + G_2 - L_{pg} - (L_{b0}-Y_T-Y_L-Y_C) - RSL_{TH}. \qquad \text{(F-7)}$$

As a mathematical convenience, let $S_0 = P_T + G_1 + G_2 - L_{pg} + Y_T + Y_L - RSL_{TH}$. Then (F-7) becomes

$$RSL(q_T,q_L,Q) - RSL_{TH} = S_0 - L_{b0} + Y_C. \qquad \text{(F-8)}$$

Apply the conditions of (F-6) by equating the right-hand side of (F-8) to zero, and utilize the expression for Y_C given by (C-11) in Appendix C to obtain

$$\sigma_C Z_0(Q) = S_0 - L_{b0}. \qquad \text{(F-9)}$$

Now use (C-7b) in Appendix C to solve for Q as

$$Q = 0.5 + 0.5 \text{ erf } \left[(S_0-L_{b0})/\sqrt{2}\,\sigma_C\right]. \qquad \text{(F-10)}$$

Equation (F-10) expresses the probability that received signal level, a function of q_T and q_L, will exceed the threshold for received signal level. That is, (F-10) expresses the communication reliability as a probability that received signal level will exceed the received signal level threshold a specified fraction q_T of the time at a specified fraction q_L of all possible locations.

Any area within the limits of the topographic base, up to a maximum size of 2^o latitude by 2^o longitude, may be specified for plotting equal-value contours of basic transmission loss, power density, received signal level, and communication reliability about a specified point within the area. Appendix C discusses the Longley-Rice propagation loss model which

is used in the point-to-point mode to statistically estimate signal attenuation to many points within the area. These estimates of signal attenuation are used to calculate the data which can be contoured.

It is of interest to discuss the algorithm used to select the points, each used with the specified point to form the many point-to-point paths for signal attenuation calibrations. Only two basic schemes seem likely as candidates. One scheme we shall call the "grid method"; the other scheme is the "radial method." Simply stated, the grid method requires the geographic area of interest to be covered by grid lines with appropriate separations, and each grid line intersection defines a point which with the transmitter location forms a propagation path. The principal advantages of the grid method are the ease of defining the points and the uniform distribution of the points. The principal disadvantage of such a scheme is that, in general, a unique path profile must be generated for the path to each point. With 1 km separation between points, more than 45,000 path profiles could be required. In simple terms, the radial method requires the selection of a number of radials, with uniform azimuth angle separation, extending from the transmitter location to intersection with the area boundary. Points then are selected at fixed intervals along each radial to form propagation paths with the origin. The disadvantage of this method is that uniform distribution of the points is impossible, although an algorithm will be discussed which achieves approximately uniform distribution. A very attractive feature of the radial method is the necessity to generate path profiles only for each radial, thereby utilizing a single (radial) path profile for many propagation paths along that radial. An innovative scheme which provides approximately uniform distribution of points involves disregarding points near the origin along certain radials. Within a 45° sector, each time the azimuth angle increment between radials is divided in half, the distance from the origin is doubled at which points along the radial are used first for establishing propagation paths with the origin. For radials at 0°, 45°, 90°, etc., points separated by 1 km starting at a point 1 km from the origin are used. For radials at 22.5°, 67.5°, 112.5°, etc., points separated by 1 km starting at 2 km from the origin are used. For radials at 11.25°, 33.75 , 56.25°, etc., points separated by 1 km starting at 4 km from the origin are used. Table F-1 shows the relationships between azimuth

angle increment, distance from origin at which new radials begin, and total number of required radials in 360°. For example, if a particular analysis involves maximum radial distances of 100 km, Table F-1 shows that only 512 radials will be required, angular separation between radials will be 0.70°, and propagation paths will begin at distances of 1, 2, 4, 8, 16, 32, and 64 km from the origin. Figure F-1 shows the starting point methodology.

Table F-1. Tabular Information on the Radial Method for Developing Data to be Plotted as Equal-Value Contours

Radial Separation Increment, Degrees	Minimum Path Length, (2^n), km	n	Total Number of Radials in 360°
90	1 (defined)	-	4
45	1 (defined)	0	8
22.5	2	1	16
11.25	4	2	32
5.63	8	3	64
2.81	16	4	128
1.41	32	5	256
0.70	64	6	512
0.35	128	7	1024
0.18	256	8	2048

Figure F-1 is a pictorial presentation for a 45° sector of essentially the same information given in Table F-1. Note from the figure that the separation between data points along each radial is always 1 km, and from radial to radial the separation varies from 0.79 to 1.57 km. The restriction of 2° latitude by 2° longitude for the geographical area limits maximum radial length that must be considered. If the origin were located at one corner of the area, the radial extending to the opposite corner would be only slightly more than 300 km maximum in length.

In Appendix D, it is stated that the interval for path profile points is fixed at 250 m for radial paths. That interval is a convenient modulus for the 1 km interval at which basic transmission loss data are calculated, as discussed in this appendix. Yet one quickly realizes that, in general,

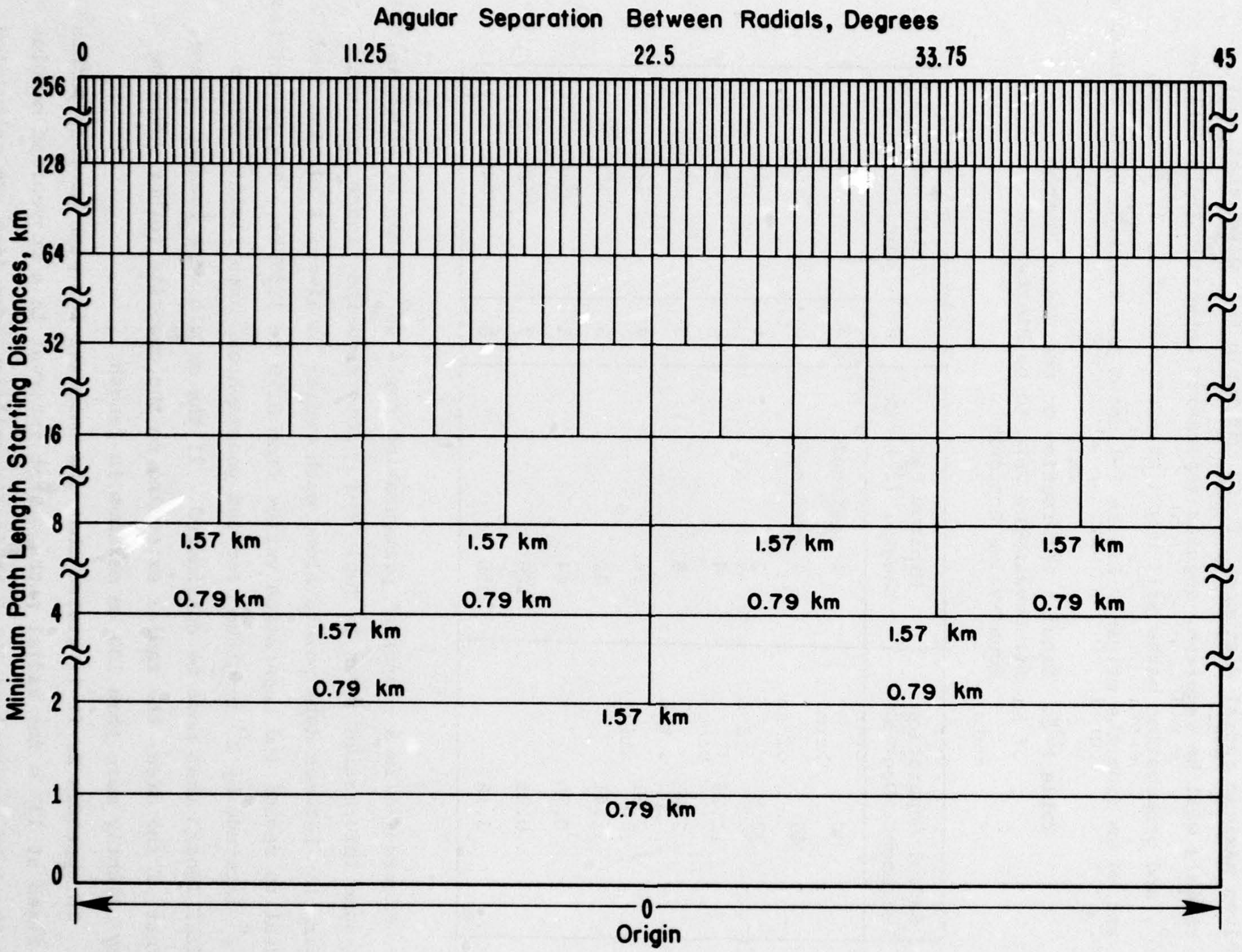

Figure F-1. Pictorial presentation of minimum path lengths, angular radial separations, and point separations for radial method.

the radial path length resulting from the intersection of the radial with the area boundary will not be integer. This problem is solved by rounding up to the next integer value (in kilometers), computing the geographic coordinates for the radial path endpoint beyond the area boundary, and using that path in the generation of the radial path profile and calculations of data to be contoured. The contouring subroutine simply is restricted to plotting within the area boundaries.

Output plots of basic transmission loss, power density, and received signal level may contain up to ten contoured values. Program logic determines the number of and the values for the contour levels in the following way. The range in values throughout the geographical area for a particular parameter, i.e., basic transmission loss for $q_T = .95$, $q_L = .95$, and $Q = .50$, is determined. That range is divided by 5, 10, 15,... to obtain the number of subintervals, limited to ten maximum with smallest subinterval value. Subinterval values are rounded up to values divisible by five and these become the values at which contours are plotted. The CSPM user specifies the values up to four possible, at which contours of communication reliability are to be plotted.

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Communication system designers and engineers often must decide whether to use design-aid models not well suited to the problem at hand or to perform many tedious and laborious hand calculations which, coupled with certain "rules of thumb," provide an estimate of system performance. The model documented in this report provides relief from such problems. For communication systems which operate at VHF and higher frequencies, the character of the terrain between the transmitting and receiving antennas, as well as the heights of the antennas above immediate terrain, will affect significantly the attenuation of the radio signals. The model reported herein considers these terrain influences, along with other commonly considered influences, by automatically accessing digitized topographic data files to develop the path data needed to compute the basic transmission loss. Computation of the basic transmission loss is accomplished using the Longley-Rice formulation for point-to-point paths. The statistical character of the basic transmission loss results from long-term fading (time availability), path to path →

16. Key Words *(Alphabetical order, separated by semicolons)*

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ABSTRACT (continued)

differences (location variability), and prediction confidence considered in the model. The type of model output data is selected by the user. Options range from simple path terrain information to basic transmission losses to utilizations of the basic transmission loss in computing power density or received signal level. There is, in addition, an output option which portrays predicted communication reliability as the probability that received signal level will exceed a specified threshold for specified conditions of time availability and location variability. All output options will provide data in either tabular or plotted form. Plotted output data are contoured over a geographical area not to exceed two degrees latitude by two degrees longitude.